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HANDLING QUALITIES REQUIREMENTS AS INFLUENCED BY PILOT EVALUATION TIME AND SAMPLE SIZE

Prepared for:
Bureau of Naval Weapons

FINAL REPORT

By: E.A. Kidd and G. Bull

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FOREWORD

This report was prepared for the United States Navy by the Cornell Aeronautical Laboratory, Inc., Buffalo, New York, in fulfillment of the requirements of Contract NOw-60-0393.

The work reported herein was performed by the Flight Research Department under the sponsorship of the Bureau of Naval Weapons. Messrs. William Koven and Harold Andrews of the Stability and Control Section, Airframe Design Division provided technical administration of the project.

The flight tests were conducted at the Naval Air Test Center, Patuxent River, Maryland. Office facilities and maintenance assistance were provided by the Flight Test Division. The evaluation tests were performed by pilots from the Flying Qualities and Performance Branch of the Flight Test Division, and by staff pilots from the Test Pilot School.

The cooperation and assistance given by all Naval personnel involved is gratefully acknowledged.

ABSTRACT

Two flight evaluation test methods for determining aircraft handling qualities requirements have been investigated and are compared in this report: 1) limited evaluation time with only five to seven minutes allowed per configuration, including comment time, for a sample of 15 pilots; and 2) unlimited evaluation time with no time restrictions for a sample of 3 pilots. Naval Air Test Center pilots accomplished the flight evaluations in the Cornell Aeronautical Laboratory longitudinal variable stability B-26 airplane. The limited evaluation data exhibit a tendency toward compression of the rating scale in that a smaller range of ratings is used as compared with that used in the unlimited evaluation but the difference is not large. The unlimited evaluation time method is shown to be superior for handling qualities research.

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SECTION I
INTRODUCTION

Investigations using variable stability airplanes (e.g., References 1 and 2) have been accomplished toward the determination of longitudinal handling qualities requirements. This work has generally utilized from one to three pilots in flight evaluations in which pilot ratings comprise the measuring tool. Such investigations usually allow the pilot an unlimited time for the evaluation and rating of each configuration. This method results in time requirements approaching as much as 30 minutes for each configuration evaluated (Reference 8). It is evident that this time requirement limits the number of pilots and the number of repeat evaluations by each pilot that can be employed in a given program. As a result flight evaluations generally employ only from one to three pilots. Although such small-size pilot samples have resulted in much good data in this area, the question of the general applicability of such data has continually arisen. The need has long existed for a comparison of the results of many pilots with those obtained with only a few pilots.

Flight evaluations by many pilots of a representative range of handling qualities can be obtained in a wieldy program only if the evaluation time allowed per configuration is limited. Thus, a test of the question of the effects of sample size will usually also include a comparison of evaluations employing unlimited pilot evaluation time with those employing some arbitrary time limit.

Therefore, the Cornell Aeronautical Laboratory, under Bureau of Naval Weapons sponsorship, undertook a program designed to supplement and extend the tests of References 1 and 2 by using more pilots. The tests were designed to compare the relative value of short-look evaluations with many pilots and long-look evaluations with a few pilots. The same variable stability B-26 which was used in the tests of Reference 1 was already stationed at the Naval Air Test Center, Patuxent River, Maryland in connection with another project. This airplane and its crew were utilized on the project reported herein to take advantage of the ready availability of the large pool of trained test pilots at the Test Center. The test airplane, presently owned by the Cornell Aeronautical Laboratory, was developed and has been used for studies of handling qualities under Air Force and Navy sponsorship.

Some words are used with a special meaning in this report, and these words will be discussed here. Each combination of stability and control characteristics is referred to as a "stability configuration", or just plain "configuration". The word is used herein to mean the set of aircraft characteristics which are kept constant for a given test run. Although the actual physical shape of the airplane was unchanged as the stability characteristics were altered through the variable stability system, the term "configuration" was used naturally by the pilots to denote the different sets of stability characteristics and it is so used here.

The tests in which many pilots fly each stability configuration for a limited time before evaluating it will be called the "short-look" tests, while those in which the pilots fly each configuration for an unlimited time before recording their comments and ratings will be called the "long-look" tests.

Pilot rating, as used in this report, is the rating of the pilots as to the suitability of a given set of stability characteristics for performing a given task. The rating is determined individually while each pilot actually performs the task, or at least the components of the task, and includes his evaluation of the effort, skill, concentration and the practicability of any special techniques required to accomplish the task as well as his performance in actually accomplishing it.

SECTION II
EQUIPMENT

The airplane used in these tests was the same variable stability Douglas B-26 (Figure 1) used in the tests of Reference 1. The theory and operation of the equipment were described in References 4 and 5. Briefly, the variable stability equipment varied the static and dynamic stability and the control force characteristics over wide ranges in flight. A large variety of handling qualities was presented to the pilot in a reasonably short time and all in the same airplane, eliminating the effects of changes in cockpit environment which would occur if the differences in handling qualities were obtained by flying different airplanes. Furthermore, with the variable stability airplane, independent control of the variables allowed investigation of the effects of variables singly and in combination.

The longitudinal variable stability B-26 was developed by Cornell Aeronautical Laboratory under Air Force sponsorship, and has been used in a number of handling qualities investigations conducted by the Cornell Aeronautical Laboratory under Air Force and Navy sponsorship. The frequency responses of the elevator and stick servos are shown in Figures 2 and 3. The stick servo provided the motion of the pilot's stick as he applied force on it. The elevator servo responded directly to the stick force exerted by the pilot, and so the pilot's commands were transmitted directly to the elevator without the intervention of the stick servo frequency responses.

The variable stability equipment was calibrated in flight to obtain a plot of frequency and damping of the short period longitudinal motion as a function of settings of the variable stability equipment. The static gains of the variable stability channels were checked each day before flight, and the dynamic response of the servos to a step input was observed. The frequency response of the servos was checked at each airplane 100-hour check, and at occasional times between airplane checks. In addition, the safety pilot noticed the dynamic performance of each configuration as it was presented to see if it was what he expected. Since the tests were repeated many times and were preceded and intermixed with a stability demonstration program using the same airplane, the safety pilot became quite familiar with the appearance of the motion in response to an elevator pulse and could maintain a running check on the behavior of the equipment as well as detecting gross errors in setting up each configuration. Gain changes in the equipment were rare during the course of the evaluation program, and the repeatability of the configurations was good.

The flight evaluations were done at the nominal test conditions of 200 mph IAS and 8000 feet pressure altitude. During the maneuvers the speed changed somewhat, and the pilots were instructed to keep the speed between 180 and 230 mph. Outside of this range the alteration of the stability characteristics with speed became noticeable. The speed limitation meant that the dives for tracking ground targets had to be relatively shallow to allow a sufficiently long time for the pilot to observe how the characteristics affected his ability to acquire and track a target.

The stick force per g was maintained constant at 40 lb/g for all of the test configurations. This value was considered reasonable and pleasant for the

test airplane, although it is high by fighter airplane standards. Stick travel per stick force was constant at 0.07 in./lb (14.3 lb/in.). Friction in the elevator control system was essentially zero while the variable stability system was in use. Values of the coefficients of pertinent longitudinal transfer functions are given below.

Pitch rate ($\dot{\theta}$) and normal acceleration (n_z) per elevator input (δ) may be defined as follows for the short period response at constant airspeed with lift due to elevator deflection, L_δ , assumed zero:

$$\frac{\dot{\theta}}{\delta} = \frac{M_\delta (s + L_\alpha)}{s^2 + 2\zeta\omega s + \omega^2}$$

$$\frac{n_z}{\delta} = \frac{M_\delta L_\alpha V/32.2}{s^2 + 2\zeta\omega s + \omega^2}$$

where for the B-26 at the above test conditions:

L_α , lift per unit angle of attack / mV = 1.2 (1/second)

M_δ , pitching moment per unit elevator deflection / I_y = 10.2 (1/sec^2)

m , mass = 834.5 slugs

V , true airspeed = 331 ft/sec

I_y , moment of inertia about fuselage reference pitch axis = 65,700 slug-ft^2

ζ , longitudinal short period damping ratio

ω , longitudinal short period natural frequency (rad/sec)

s , Laplace operator.

Phugoid characteristics were maintained at a period of 50 seconds and a damping ratio of 0.05.

The airplane was limited to an acceleration of 3.5 g, and 2 to 2.5 g was the maximum normally used. The limitations on speed and accelerations were considered to be not too restrictive for evaluation purposes, but the pilots did recognize that these limitations plus the other characteristics of the airplane (such as a low maximum roll rate) made an exact simulation of some fighter and attack tactics impossible.

SECTION III
DESIGN OF THE EXPERIMENT

The acceptable and unacceptable regions of frequency and damping of the short period longitudinal motions were determined in the tests of References 1 and 2. The object of this investigation was to confirm these regions, or indicate revision, and to compare two different test techniques. The stability characteristics which were chosen as test points were therefore selected in the marginal regions to help define the boundaries. Figure 4 shows the points selected on a grid of short period natural frequency vs. damping. Included are lines separating good and bad regions on the plot as determined from pilot rating data in the handling qualities studies of References 1 and 2. Several points were chosen as repeat points to be flown twice by a given pilot to obtain information on the repeatability of the rating data.

The higher frequency range of the data of Reference 2 could not be covered in this investigation due to limitations of the variable stability equipment in this airplane.

The order in which the stability configurations were presented to the pilots was randomized, and each pilot was presented with a different random order. The tables of random order of Reference 6 were used to set the configurations in random order.

It should be noted that the experiment was designed from the outset to use pilot ratings rather than task performance as a measure of the goodness of a stability configuration. The weakness of task performance measures in airplane handling qualities work is the difficulty in choosing tasks and parameters to measure which can be shown to give a valid measure of the over-all goodness of the stability configuration. Another difficulty arises from the ability of the pilot to compensate for the deficiencies in the handling qualities, making the task performance measurements relatively insensitive to changes in the handling qualities. This effect, which has been noticed in some previous handling qualities studies, such as References 7 and 8, has recently received some clarification from studies of the representation of a human controller from a servomechanism viewpoint. Reference 9, for example, sets up a servo model of the human which fits experimental data, and then shows how the human alters his characteristics to fit the dynamics of the device he is operating, and how his opinion of the goodness of the device can be related to the amount that he has to alter his characteristics to maintain his task performance. This promising line of attack has not yet progressed to the point where we can dispense with experimental determination, in a realistic situation, of the suitability of various handling qualities as determined by pilot ratings. The complexity of the interrelation between handling qualities requires a high degree of realism in the tests to compensate for the inability of the experimenter to control all the necessary variables, or sometimes to know all the variables which are, in fact, affecting the pilot. The variable stability airplane is particularly well suited to this kind of testing because it provides a high degree of realism with convenient control over some of the important variables.

Some special considerations were required in the comparison of the results of the two test techniques. If the long-look results were different from the

short-look results, it would be important to see how those particular pilots had compared with others when they were using the short-look technique. In other words, it was necessary to show whether the difference, if any, was due to the technique or to the particular pilots. Therefore, the long-look pilots were selected from the larger pool of short-look pilots. The long-look test points included all the sixteen short-look points, plus six repeat points plus eight additional points. Thus, a direct comparison between ratings for the two test techniques was possible.

SECTION IV
TEST TECHNIQUES

Subjects

All subjects in the evaluation flights were pilots at the Naval Air Test Center, Patuxent River, Maryland. All had had training as test pilots and were either active test pilots or were on the staff of the Navy Test Pilot School at Patuxent. All were Navy or Marine pilots with operational experience. All of the pilots had become familiar with the B-26 airplane and the variable stability equipment during a stability demonstration program in which various aspects of longitudinal stability and control were demonstrated and discussed in flight. This program, conceived as a sort of laboratory course to supplement the academic courses on the subject at the Navy Test Pilot School, consisted of two flights, each of two hour's duration. None of the pilots had recent B-26 experience other than this.

Instructions to Subjects

The subjects were given a short talk covering the purpose of the tests, the technique to be used, and the interpretation of the rating scale which was used. An outline of the briefing is included as Appendix A. The pilots were told the two separate aims of the project, namely, additional data to define the boundaries between good, medioc re, and bad combinations of frequency and damping of the longitudinal short period motions, and the comparative effectiveness of long-look and short-look evaluation techniques. The pilots knew that the lateral-directional characteristics of the airplane remained unchanged.

The maneuvers to be used were discussed and the point made that additional maneuvers could be added if the pilot chose to include them. The use of the comment card was discussed, both as a check list to ensure that important observations were not inadvertently left out and as an aid in helping the pilot to focus his ideas on a given stability configuration. The cards used in flight, listing the desired maneuvers and the items to be commented upon, are shown in Tables I, II, and III. The comment data is useful to the analyst to discover the reasons for the pilot's rating, and the importance of the comments was pointed out to the pilots.

A discussion of the rating scale was given to promote uniformity in the interpretation of the scale. Since the ratings assigned might vary with the intended use of the airplane, the pilots were allowed to assign two ratings, one for the airplane as a tactical machine and the other rating on its flyability in general. There was some difficulty here, since the B-26 was not a modern fighter, in deciding what kind of tactical airplane it might reasonably represent. For the purpose, a tactical airplane was defined as one in which rapid and precise maneuvering and tracking would be required, as well as considerable cruising under instrument conditions. Only four pilots gave two ratings for each configuration; the other pilots gave only the tactical rating. In this report only the tactical ratings are presented. In general, a configuration was rated about one unit more favorable (lower score) for utility purposes than for tactical purposes.

The pilots were told to consider that their evaluation and ratings did carry some weight, and to consider the consequences of applying a given rating. They were told that aircraft designers would utilize the results of their evaluations in

making design decisions regarding handling qualities. For example, if they were extremely demanding and would accept nothing but the best handling qualities, they might make unacceptable a design which could have given them markedly increased performance if they had been willing to accept somewhat inferior handling qualities as the price they had to pay. On the other hand, if they were too lenient and applied a "poor but still acceptable" rating to a configuration which was in fact nearly unflyable, they were thereby sanctioning the purchase of an airplane with these poor characteristics and might find themselves making a carrier approach to a pitching deck some dark, rainy night and wish they had been more realistic in their evaluation.

The pilots who did the long-look evaluations had, of course, already performed a short-look evaluation. The differences in test technique were explained, with emphasis on the fact that they had essentially no limit on the time for each configuration and could therefore fly long enough to become familiar with some unusual but perhaps acceptable characteristics.

During the flight the safety pilot monitored the comments and ratings as the pilot gave them and attempted to spot ambiguous statements or omissions and have the pilot clarify the point while the events were still fresh in his mind. A deliberate attempt was made to avoid influencing the pilot's ratings, either by remarks or facial expressions as the comments were being given. The pilots were told of this and were advised that a stony face and a poker expression on the safety pilot denoted neither approval, disapproval, nor a lack of interest in the proceedings, but only an attempt to avoid coloring the evaluation pilot's ratings.

The pilots were also told to expect that the evaluation procedure would be hard work and fatiguing, and to call for a break if they found their interest flagging.

Flight Technique

The conduct of the evaluation flights was standardized as much as possible to avoid the introduction of uncontrolled variables in the evaluation. A typical evaluation flight will be described, then the differences between the long- and short-look evaluations will be given.

The pilots had recently been given a stability demonstration flight in the test airplane, so they were reasonably familiar with the cockpit arrangement, flight characteristics and limitations of the airplane. They were not required to be checked out in the airplane or its systems. However, they sat in the left seat, which is the normal first pilot's position, and their controls, instrument panel and control console were standard for the B-26. The variable stability equipment was under the control of the safety pilot in the right seat and the crew member in the waist compartment.

The take-off was made by the safety pilot, but the evaluation pilot flew the airplane during the climb to the test altitude and leveled off at the test airspeed. The variable stability equipment was engaged and the first configuration set up by the safety pilot.

The standardized maneuvers listed on the maneuver card, Table I, were then per: rmed while the pilot considered how the stability and control characteristics affected his ability to do them. This set of maneuvers had been evolved

in previous handling qualities investigations, References 1 and 2, and was intended to bring out the various aspects of longitudinal stability and control in tasks representative of those encountered in tactical use of the airplane. The pilots were allowed to perform any other maneuvers they felt were helpful to them; as a matter of fact, the standard set of maneuvers seemed to suffice.

When the pilot had completed his maneuvers, he asked to have the wire recorder turned on and proceeded to comment on the configuration, using the comment card of Tables II or III as a guide, and applied his rating, using the rating scale of Table IV. One set of comments and one over-all rating was given for each configuration, except that four pilots gave each configuration two ratings - one for a tactical airplane and one for a utility airplane, as discussed on page 7. Usually the configuration was still set up while the pilot was commenting and as he described each feature and how it affected his rating, he would disturb the airplane in a manner which illustrated his point. While these demonstrations were not recorded, the fact that they existed showed that the pilot did not have to rely entirely on his memory, but was continually receiving fresh impressions of the configuration he was talking about.

Upon completion of the comments and ratings for a given configuration, the safety pilot adjusted the knobs on the variable stability equipment to set up the next configuration and the evaluation pilot started on that one.

The pilots were not told what the characteristics of each configuration were. They could get an approximate idea by applying a pulse to the elevator and observing the response of the airplane. Some did this and some did not, but in either case their comments and their ratings were tied to the behavior of the airplane in the test maneuvers rather than to the response to the pulse. In other words, they supported their ratings by phrases such as "Oscillates too much when disturbed while tracking or when first acquiring target", rather than "Response to pulse shows light damping".

The pilots were not told how their ratings compared with those of other pilots, even after their flight was completed. This was done to prevent the word from spreading around among the pilots and influencing those who had not yet flown their evaluation flight.

The flights were conducted in VFR weather where the pilot maneuvered and navigated by reference to the ground. Evaluation flying is demanding work and the addition of flying and navigating by instruments was considered to interfere too much with the evaluation task, unless the evaluation was to be primarily on the suitability of the configuration for instrument flying. Flights were not made unless the weather was good enough to allow the pilot to concentrate on the evaluation without worries as to whether the weather was becoming marginal for the operation. Although occasional patches of turbulence were encountered, the air was generally smooth during the tests. The flight test altitude was usually 8000 feet, but was varied from 5000 to 10,000 feet if necessary to find smooth air.

In the short-look evaluation flights the pilot evaluated sixteen configurations. He flew each configuration for four or five minutes, then spent one to three minutes recording his comments and rating. About two hours were spent in the actual

work of the flight, plus an additional 10 or 15 minutes in take-off and landing. Twenty-four configurations in each flight had been originally selected as desirable at five minutes each. The actual minimum time turned out to be nearer seven or eight minutes, and the number of configurations had to be cut down to keep the length of the evaluation period to about two hours. The pilots felt that about two hours was the practical limit. Beyond that time they became fatigued and felt that their evaluations would suffer. The same conclusion had been reached during evaluation programs conducted in the past at the Cornell Aeronautical Laboratory. The first pilot completed the first sixteen of his randomized twenty-four configurations. When it became clear that twenty-four was too large a number, the sixteen most important configurations were selected for the rest of the flights. The first pilot therefore did not fly all of the same sixteen configurations as the rest of the pilots did. Equipment trouble on one flight required two flights by that pilot to complete his evaluation. All the rest of the evaluation pilots completed the same sixteen configurations in one flight, as scheduled.

The pilots were offered a short rest period during the flight, but most of them preferred to get on with the evaluation and did not accept the offer. The safety pilot noted the time spent on each configuration and if the evaluation pilot began to take too long on each configuration, the safety pilot pointed this out and speeded him up.

The long-look program differed in the length of time spent on each configuration and in the details of the comment and rating technique. The same maneuvers were performed, but the pilot was allowed as much time as he felt was useful on each configuration. The total time on each configuration varied; very good or very bad configurations did not take long as a rule, but marginal or unusual ones took longer. Three to six configurations were evaluated per flight, with five being the most common number.

Data Collection

The data appeared in two forms: a rating of the desirability of the configuration and comments as to the aspects of the characteristics which led to the rating.

The rating scale used, with definitions, is shown in Table IV. This ten-point scale has evolved in past handling qualities tests performed by the NASA and CAL and is generally equivalent to the scale (Reference 10) used in NASA handling qualities tests. However, there are differences. The concept of normal, emergency, or no operation is not included in the CAL scale. Also, test and mission definitions are part of the pilot orientation for the particular evaluation and not part of the rating scale. Thus, the rating becomes a measure of the suitability of a particular configuration for the stated mission being evaluated - in this case, a tactical airplane requiring rapid and precise maneuvering and tracking.

The whole scale, with the definitions as shown, was mounted in the airplane in easy view of the pilot to help him keep his use of the ratings as uniform as possible. Previous handling qualities tests at CAL had shown that a scale of about ten points was right for handling qualities work. A scale with many more

points produced overlapping ratings and one with fewer points led the pilots to interpolate intermediate ratings.

The ratings were supposed to be given on an absolute rather than relative basis. That is, each configuration was supposed to stand by itself rather than be rated in comparison with some other configuration. The ratings were given in terms of whether the stability characteristics facilitated or interfered with the performance of the maneuvers. In practice, of course, the pilots were using their experience with other airplanes as some sort of a guide, but the ratings for each configuration were given independently without apparent comparison with other configurations.

Comments were solicited to determine what aspects of the motion of the airplane affected the rating. This information allows the analyst to present the results of the evaluation in terms which have more utility to the airplane designer. The comment cards of Tables II and III were used to force a comment on each aspect of interest to assure the analyst that each aspect had been looked at and considered. Otherwise, he could not tell whether lack of a comment meant that the pilot considered the item unimportant or that it had been overlooked. The comment card also served to help the pilot clarify his ideas in preparation for rating the configuration. The pilots were aware of the fact that the configurations were presented in a random order which varied from flight to flight, and that comments comparing a configuration with the preceding one were not, therefore, very helpful. They therefore attempted to make their comments self-sufficient for each configuration rather than relative.

Comments and ratings were recorded in flight on a wire recorder. The ease of talking compared to writing encouraged the pilots to amplify their comments more than they would have done had they been required to write them out.

SECTION V
STATISTICAL COMPARISON OF TEST METHODS

In this section the two evaluation test methods will be compared to determine if differences in ratings are realized when the evaluation time allowed each pilot is limited as compared with the usual method of allowing unlimited evaluation time. This comparison is made through appropriate statistical techniques and by the use of descriptive plots of the data obtained. The information analyzed here consists entirely of the category rating numbers determined by each pilot for each configuration evaluated. The basic statistical analysis procedures used throughout are taken from References 6 and 11. The data obtained from each of the two test methods is analyzed separately to give the variability among pilots and the factors contributing to this variation. After this analysis, the rating data obtained in each of the two test methods are compared and the effects of sample size are discussed.

Limited Evaluation Time

The pilot rating data obtained in this phase of the investigation are presented in Table V. An analysis of these ratings was made to determine if significant differences existed between pilots. The basic analytical tool employed was an analysis of variance.

It was assumed that each pilot's rating of each configuration was a sample from a normal distribution. That is, if each pilot were given each of these configurations to rate a number of times, the resulting ratings for each configuration would form approximately a normal distribution. This assumption is inherent to an analysis of variance. This type of analysis also requires that the sample variances be homogeneous. A Chi Squared test (Bartlett's) for the homogeneity of variances for the data from pilots A through N and all configurations shown in Table V, except configuration 27, revealed no significant differences in the variances among either the data for each configuration or the data for each pilot. Pilot O was not considered in this analysis nor in the following analysis of variance as his test program could not be completed. Configuration 27 was omitted also from this analysis as pilot A inadvertently was not given this configuration. It would be possible to utilize suitable statistical techniques for filling in this particular rating, but it did not seem worthwhile for this analysis. The loss of the data for this particular configuration does not change the conclusions resulting from the analysis of variance.

Details of the actual statistical findings are presented in Appendix B, items 1 - 3. This analysis demonstrated a significant difference in the ratings of pilots A through N (all the pilots). The standard deviation due to pilots – interpilot variability – was found to be 0.66 rating. In order to investigate the source of this variation among the pilots, histograms of each pilot's ratings were constructed as presented in Figure 5. It should be noted that these distributions should not necessarily be normal as they are functions of the particular configurations evaluated, and the configurations were chosen on the basis of other reasons rather than the distribution of their expected ratings. Examination of these histograms and one of the distribution of the means for each pilot (also shown in Figure 5) indicated that pilots B, F, G and H were most likely those contributing to the significant differences found for this particular set of pilots.

That is, the orientation of these pilots with regard to the rating scale or with regard to their own particular evaluation as to what was desired, was shifted toward a higher (worse) mean rating. As indicated in Appendix B, an analysis of variance excluding only pilots B, G and H was first made and significant differences among the remaining pilots still existed. It was only when pilot F was also omitted from the analysis that no statistical differences were found.

For each of these three analyses of variance in Appendix B, the standard deviation due to configurations remained essentially constant. This indicates that the omission of the four pilots had no effect on the variance of the ratings due to configurations. Also, the standard deviation due to error remained essentially constant. This error value of $\sigma = 1.3 - 1.4$ is a measure of the experimental error due to sampling and includes effects not otherwise allowed for such as intrapilot variability and possible variability in repeating configurations.

This heuristic use of the analysis of variance was employed only in an attempt to isolate the contributions to the significant differences found. For the experiment as a whole, it must be stated that significant differences among the pilots were found. However, if the aforementioned pilots are removed from the data, the pilot ratings among the ten remaining pilots are not significantly different statistically. There are no a priori reasons for exclusion of these pilots. The actual causes for their higher (worse) average ratings can only be surmised. As discussed later there are reasons against exclusion of the data of these four pilots from the results.

There is no evidence that particular configurations were contributing to the rating differences among pilots. Histograms of the ratings by each pilot for each of the particular configurations are presented in Figure 6. There are obvious differences in the distribution of ratings for each of these configurations, but there are no specific configurations that are obviously contributing to the disparity among the pilots. In examining these histograms, it must be remembered that each pilot was given only a total of 5 - 7 minutes to maneuver the aircraft, evaluate its handling qualities in terms of the rating scale, and provide a numerical rating. The ranges in ratings of as much as 7 points that were obtained for particular configurations seem inordinately large. However, range is an inefficient statistic in estimating variance and its efficiency is strongly affected by sample size.

The sample standard deviations determined for each configuration for the short-look ratings by pilots A-N are presented in Table VII. These values include the total sampling variations for each configuration; they are not the same measures of standard deviation due to pilots previously discussed in the analysis of variance. It is assumed that the variability in the configurations evaluated, due to gain changes in the variable stability system, is constant. Therefore, the changes in standard deviation with configurations may be attributed to pilot rating technique. These sample standard deviations are compared in Figure 7 with the mean rating for each configuration as given in Table V. The linear correlation between these two statistics is not significant. However, there are indications that this standard deviation is a function of mean rating, as indicated in Figure 7, with the peak variation appearing in the 4-5 rating range. Linear correlation coefficients are indicated in Figure 7 for the data in two separate groups -- the upper and lower ranges of mean rating. Although only in the upper range of rating is statistically significant correlation demonstrated, the correlation

coefficient for the lower range strongly suggests that standard deviation of ratings is a function of mean rating in this range also. The dashed lines constitute a least squares fit to the data assuming the error to be in the standard deviation measures.

The rating range where the maximum rating variance occurs is in that part of the rating scale where the handling qualities are neither good nor very bad. It might well be expected that in this region the variation among pilots would be the greatest; or stated another way: when configurations are either very good or very bad there is less variability in pilot ratings than when the handling qualities are intermediate.

Unlimited Evaluation Time

Pilots A, B and C rated a total of 30 configurations, using an unlimited amount of evaluation time after completion of their limited evaluation flight. Their rating data will be analyzed herein as an entity to determine the inter- and intrapilot variability before comparing the results of the two types of evaluation. The data obtained are presented in Table VI. The details of an analysis of variance of these data are presented in Appendix C. In general, the results of this analysis for all 30 configurations were as follows: 1) the mean ratings for each of the three pilots were significantly different; 2) the interpilot variability, standard deviation due to pilots, was found to be approximately 0.76 rating. An additional analysis of variance was accomplished with only those configurations which were evaluated during the short-look evaluation. The results of this analysis were similar to the analysis of variance for all configurations: 1) the mean pilot ratings were significantly different, and 2) the standard deviation in ratings due to pilots was approximately 0.68 rating.

The differences between the ratings of pilots A, B and C were examined to determine which of the pilots was contributing to the significant difference. It was assumed that each of the three possible comparisons was a separate experiment. Although this assumption may result in a total experimental error rate that is slightly larger than the assumed error rate, the conclusions drawn from the "t" tests of the differences were not affected. The "t" test of differences tests the hypothesis that the mean of the differences is not zero. This test measures the probability that the mean of the sample of differences includes zero. A value of confidence limits is selected within which the mean of the differences could be expected to occur if the experiment were repeated under the same conditions, or replicated. If the mean of the sample of differences could include zero, for this selected value of confidence limits, then there is no significant difference between the two paired samples. If the mean of the differences could not include zero, then there is a significant difference between the paired samples. Confidence limits of 95% are commonly used, although it is generally stated as a 5% probability of error.

The ratings of pilot B were found to differ significantly from those of both pilots A and C, while the ratings of pilots A and C were not found to be significantly different. These conclusions were the same for the data including all configurations and for the data including only the short-look configurations. The mean of the differences between pilot B and pilots A and C varied from approximately 1.0 to 1.5 ratings for the data of all configurations and from approximately 1.3 to 1.4 ratings for the short-look configurations. This range of mean differences

is within the range to be expected for this type of experiment. A similar range of mean differences has been reported in Reference 8 for an evaluation of longitudinal configurations in a high fidelity, fixed-base simulator.

The separation of the results into sets according to the inclusion or exclusion of pilots whose ratings have been shown to be statistically significantly different from the remainder has not been done in the belief that these excluded ratings are not valid. Rather, it has been done only to indicate the possible variation in evaluation results that might occur. In each test method, a relatively large percentage of the pilots utilized were found to differ significantly from their peers. For each method this difference was in the direction of more critical selectivity. The fact that these pilots are more demanding in their requirements on handling characteristics is not a valid reason for the exclusion of their data. Because of the nature of the rating evaluation task and each individual pilot's orientation, with respect to the rating scale and the mission being considered, it may be that significant differences in rating means among pilots will be the rule rather than the exception (significant differences will be demonstrated when generally used probability levels are employed). A pragmatic or utilitarian evaluation of the rating results obtained including these variations in means may be required rather than a specific statistical comparison with some level of significance.

During the long-look evaluation, repeat evaluations by each of the three pilots were obtained for each of six different configurations. The results of these repeat evaluations are presented in Figure 8. A "t" test of the differences for each pilot demonstrated no statistically significant differences between the initial rating and the repeat rating of a given configuration by a given pilot. This statement does not imply that there were no differences; it merely says that the difference between the initial and the repeat rating is randomly scattered and does not show a pattern such as the repeat rating being always higher (or lower) than the initial rating. Inherent in the "t" test is the assumption that variance does not vary significantly as a function of rating, that is, the scatter is similar for low, medium or high ratings. In the discussion of interpilot variability in the short-look evaluations (pp. 13-14), the variance was shown to be higher for the medium ratings than for the low or high ratings. Thus the scatter was not independent of the value of the rating, violating one of the assumptions upon which the "t" test is based. This suggests that the "t" test as applied to intrapilot variability may not be valid. Determination of intrapilot variability was not a primary objective of this project, and the data obtained from the relatively small number of repeat runs is insufficient to show whether the variance of the ratings by one pilot was a function of the rating itself. However, the "t" test is relatively insensitive to departures from the assumptions upon which it is based, so the information given by it, coupled with the appearance of the plots of Figure 8, confirm the statement that repeat ratings by a pilot do not show a systematic difference from his initial ratings.

Standard deviations about the line for perfect agreement (line with slope equal to 1.0 in Figure 8) were determined as follows:

Pilot	Standard Deviations
A	1.0
B	1.2
C	0.8

These values of standard deviation are approximate estimates of each pilot's variability as if he were repeating the evaluation of a single configuration. If a large sample of data were obtained, a slope value of 1.0 (or zero mean error between the first and second ratings) would be the best estimate for the population and is therefore the reference about which these standard deviations were measured.

The sample size from which these measures of intrapilot variability were obtained was rather small. However, the values obtained are within the range measured for each of two pilots in the investigation of Reference 8. These standard deviations include possible contributions due to variations in repeated configurations as a result of variable stability system variations.

Effect of Sample Size

It has been shown in the discussion of the data obtained with limited evaluation time that the statistically significant difference among pilots can be eliminated by removing the data for four of fourteen pilots. This is a demonstration of an effect of sample size. In any sample of pilots selected for this type of research, the mean ratings for each pilot of the configurations evaluated will form some distribution. The distribution resulting from this investigation has been discussed and is shown in Figure 5. It is apparent that comparison of different sample sizes depends entirely upon that part of the distribution into which particular samples happen to fall.

The sample comparison that is important to this analysis is the one that compares pilots A through C with pilots D through N. Pilots A, B, and C were used in both the short- and long-look test methods. The validity of the comparison of the two test methods will be enhanced if these three pilots are representative of the entire group of short-look pilots. These three pilots were selected only because of their availability for this particular program. No attempt was made to select them on the basis of skill as pilots or experience in flight testing.

Examination of the distribution of the mean ratings for each pilot (Figure 5) suggests that their ratings might well be representative of the group as a whole. Also, it has already been determined, earlier in this section, that pilots A and C were part of the group of ten pilots whose ratings were not significantly different while pilot B was one of the group of four pilots whose ratings were significantly different from the group of ten. Additional statistical evidence is presented in Appendix B, item 4. The analysis of variance of item 1 of Appendix B is expanded to include a comparison of pilots A through C with the remaining short-look pilots, D through N. These two groups are not significantly different.

Thus, all evidence leads to the conclusion that pilots A, B, and C are representative of the entire group of short-look pilots.

Comparison of Results with the Two Test Methods

In comparing the short-look test method with the long-look test method, each pilot's ratings for the two methods were paired for each configuration tested. The difference between each of these ratings was determined and a "t" test of these differences made. No significant differences were measured in each of the three pilots' (A, B and C) ratings by the two test methods.

However, this test of differences will not necessarily show up systematic functions of differences. Therefore, the differences between the two test method ratings, long-look minus short-look, were plotted versus the long-look ratings and are presented in Figure 9. Correlation coefficients were calculated for each of these three sets of data and are presented on Figure 9. A significant correlation was determined in the data of pilots B and C. A least squares fit to these data is indicated by the dashed lines on Figure 9. This least squares fit assumes all the error to be in the short-look data. It is concluded that pilots C and B tended to reduce the range of ratings used in the short-look evaluation as compared with the range used in the long-look evaluation. That is, configurations rated poorly during the long-look evaluation were rated as better during the short-look evaluation and configurations rated as good during the long-look evaluation were rated less good during the short-look evaluation. This tendency toward "centration" in use of the rating scale during the short-look evaluation is not apparent in the data of pilot A.

A further study of this phenomenon of "centration" is presented in Figure 10. Here the means for each of the short-look configurations are plotted versus the corresponding means for the three pilot long-look evaluation. The two possible least squares fits to these data are indicated: b_{yx}, assuming all the error to be in the short look data; and b_{xy}, assuming all the error to be in the long-look data. Figure 10 includes a line of perfect agreement, i.e., a line plotted to illustrate how the data would look if the short-look and long-look tests produced identical results. It is apparent that, for the samples of pilots and configurations evaluated in this investigation, limiting the evaluation time results in a reduction of the total range of rating scale utilized by the pilots. When a limited time evaluation test method is used, the evaluation pilots do not have the opportunity to adequately investigate a particular configuration for all the pertinent maneuvers or to get a feel for its particular idiosyncrasies. Apparently there is a tendency to down-rate a particularly good configuration, due perhaps to a concern that it may have less good features that were not seen in the short time available. Similarly, there may be inadequate time to explore poor configurations to ascertain if they have even more degraded characteristics than are apparent for a limited look.

SECTION VI
PILOT RATING BOUNDARIES

In this section, the pilot rating boundaries are presented and the results obtained from the short-look tests are compared with results of the long-look tests. Results obtained in this flight program are compared with those of other programs, including both flight and ground-based simulator tests. Observations made by the safety pilot, relating scatter in the ratings to pilot techniques, are presented and discussed.

Evaluation Data

The evaluation data obtained in this investigation are presented in Figures 11 through 14 as plots of mean pilot rating vs. short period natural frequency, ω, and short period damping ratio, ζ. Based upon past experience, some liberties have been taken in fairing smooth curves through these data. Little difficulty was experienced in fairing the short-look data (Figures 11 and 12). This is attributed to the smoothing that results from the use of means of large samples. The long-look data, obtained with only three pilots, has considerably more scatter which resulted in more difficulty in curve fairing. A good example of this is in the data for 0.3 natural frequency. In the short-look ratings (Table V) three pilots, B, D, and F, rated 0.8 damping ratio at least two rating points worse than 0.4 damping ratio. The remaining pilots did not show this decrement, in fact the majority preferred a damping ratio of 0.8 over 0.4. Averaging the data from 14 - 15 pilots, a relatively flat pilot rating curve for $\omega = 0.3$ above $\zeta = 0.4$ is obtained whether all pilots are included (Figure 11) or whether pilots B, F, G, and H are eliminated (Figure 12). In the long-look data with only three pilots, the similar strong down-rating of the configuration $\zeta = 0.8$ by pilot B results in a relatively sharp peak in the ratings for $\omega = 0.3$ at $\zeta = 0.4$ (Figure 13). When only pilots A and C are considered in the long-look data (Figure 14) this rating curve for $\omega = 0.3$ has a shape quite similar to that for the short-look data. Thus, the comparison of the short-look and long-look rating curves is affected by the sample sizes in a manner additional to that discussed in the previous section. Individual pilot ratings have more influence on the means of small samples than of large samples – an obvious but important consideration.

Effect of Pilot Technique on Ratings

The preceding statistical discussion considers the information which a statistical analysis can extract from the data. In some cases additional information, from pilot comments, may add to the understanding. For example, the safety pilot noticed that the rating of the low frequency, well-damped configuration ($\omega = 0.3$ cps, $\zeta = 0.8$) was more affected by pilot technique than most of the other points. Pilots seem to use one of two techniques when they are controlling an airplane. Some pilots force the motion to fit their demands, using whatever control motion is required, while others accept the type of response the airplane gives them and plan their maneuvers accordingly. The choice of technique does not seem to be a matter of skill; there are examples of good pilots for each technique. Furthermore, a pilot may change his technique. For example, a pilot who generally uses the latter technique may find himself in a situation requiring immediate action, and force the airplane to respond accordingly.

The configuration under discussion shows a response to an elevator

deflection which is typically rather slow, and does not overshoot. The natural frequency is not so low, however, that the pilot has airplane-pilot stability problems unless he applies a rather large and abrupt input.

If a pilot controls the airplane by applying an elevator input and accepting the time required for the response, he will be quite satisfied with the configuration, except, perhaps, for complaints about the slowness of the response. On the other hand, if he demands a prompt response and uses whatever elevator motion is necessary to achieve it, he will be dissatisfied with the configuration because the effort required to get the prompt response is too great. Furthermore, the large elevator motion required to produce the prompt initial response is apt to produce more final response than the pilot expected. His efforts to correct the motion of the airplane lead him to an airplane-pilot system oscillation.

The relatively low rating given to this configuration by pilot B, compared to the ratings by pilots A and C, may be due to this effect. As evidence, note the long-look comments for this configuration. Pilot B speaks in terms of force, whereas pilots A and C speak in terms of motion. The implication is that pilot B is speaking of the force required to make the airplane move the way he wants it to, while pilots A and C are speaking of the motion resulting from the control input which will eventually produce the desired final response.

As further examples of this effect, consider the long-look comments for configurations 3, 5, 6, 12, 22, and 24. Configuration 3 (ω = 0.8 cps, ζ = .5) produced a quick response due to its high natural frequency so there was no requirement for pilot B to force the motion. He rated the configuration favorably, and his comments do not mention effort required to get the response he liked. The comments for configuration 6 (ω = 0.6 cps, ζ = 0.3) reflect pilot B's effort to add damping to a slightly oscillatory configuration, and his rating here is low. Pilots A and C apparently waited for the overshoot to disappear and then we were satisfied with the motion. Notice again that pilot B comments in terms of forces, while pilots A and C comment primarily in terms of resulting motion. The same trend is evident in the comments for configuration 12 (ω = 0.5 cps, ζ = 0.4). For the lower frequency of configuration 22 (ω = 0.3 cps, ζ = 0.2) pilot B complains of the heavy stick force, which appeared because he was applying a rather large elevator motion to force a faster response than would be produced by the amount of elevator required to maintain the steady "g" he wanted. The large elevator motion then produced a response which kept building to more "g" than he wanted, so he was required to alter his elevator input. The low damping meant that the motion would be oscillatory, and in his own words, he "must fight it". Pilot C again comments in terms of the motion that resulted from his input, rather than the input required to counteract the motion.

The fact that we may understand something of the cause for a disagreement in rating does not necessarily allow us to eliminate the disagreement. We are not willing to separate pilots according to technique, because we have equally expert pilots using different techniques, and because we want the airplane to have handling qualities suitable for any reasonable pilot technique. We might point out, parenthetically, that pilot technique is rather uniform as a rule; the example of different techniques discussed above seems to be an interesting exception.

Comparison of Test Methods

The short-look data demonstrates a greater effect of short period frequency above a value of $\omega = 0.5$ than does the long-look data. The long-look data for all three pilots (Figure 13) shows little influence of natural frequency for values above 0.5, while the short-look data (Figure 11) demonstrates a marked peaking of the curves of pilot rating vs. frequency at the different values of damping ratio. Similar conclusions are evident from the short-look data which excludes those pilots found to be significantly different from the remainder (Figure 12). The long-look data with only pilots A and C (Figure 14) indicates somewhat more influence of natural frequency than the data for all three pilots but not as much effect as that noted in the short-look evaluation. The elimination of pilots B, F, G, and H in the short-look data resulted in generally better pilot ratings for all values of frequency and damping. The elimination of pilot B from the long-look data (Figure 14 compared with Figure 13) also resulted in generally better pilot ratings.

From these data two rating boundaries were determined for each of the two test methods and are presented in Figure 15. The two boundaries determined are minimum satisfactory (3.5 rating) and minimum acceptable (6.5 rating). In general, these boundaries for each test method are affected in a similar manner by the elimination of the significantly different pilots. The largest difference is apparent in the minimum satisfactory boundary as established with the short-look evaluation. When pilots B, F, G, and H are eliminated from these results a larger area of the ω vs. ζ plot is considered satisfactory. The data suggest that the four pilots who contributed to the significant difference among pilots as previously discussed were only slightly more critical in their ratings of relatively poor configurations, but were considerably more critical in their acceptance of relatively good configurations as satisfactory. This further suggests the possibility of interactions between the pilot ratings and the configurations tested.

A plot of the boundaries obtained with all pilots in both the short-look and long-look evaluations is presented in Figure 16. Included in this figure are the mean values of the actual pilot ratings for each configuration. This figure indicates graphically the differences in results obtained with the two test methods. The short-look results are more critical in their requirements on short period frequency and damping in the inclusion of configurations within the desirable areas. As configurations become less acceptable (higher rating numbers), this difference diminishes until, at a rating of 7, the results of the two methods are in good agreement for the range of dynamics tested. A major difference in the two sets of boundaries results from the better ratings for the long look at $\omega = 0.8$ cps.

Comparison with Other Investigations

In Figure 17 the long-look evaluation data obtained with all three pilots are compared with that obtained in other experiments. The unsatisfactory boundary of Reference 2 was obtained by three pilots in a variable stability F-94 with a center-stick control. Maneuvers required for each configuration were essentially identical with those of the present program. As a word rating scale was employed rather than the numerical scale, the boundaries are not directly comparable. However, the unsatisfactory boundary of Reference 2 should be

approximately comparable to the 3.5 boundary of the present investigation. This boundary of Reference 2 requires a somewhat higher frequency as a minimum and allows less damping in the upper range of frequencies than the 3.5 boundary. The evaluations in both programs were applied to aircraft in which rapid and precise maneuvering and tracking would be required. Values of pertinent parameters of the transfer functions presented in Section II are given below:

Parameter	B-26	F-94 (Ref. 2)
L_{α}	1.2	1.9
V, mph true	233	507
steady state stick force per normal acceleration, lb/g	40	6 (4.8)*
steady state pitching velocity per stick force, deg/sec-lb	0.20	0.70 (1.1)*

* values in parentheses are for one pilot - other values are for two other pilots.

The values of L_{α}, numerator time constant of the $\dot{\theta}/\delta_e$ transfer function, are not sufficiently different to cause differences in pilot ratings. The values of stick force per normal acceleration are quite different but were selected as approximately optimum for the range of parameters investigated. It is to be expected that the wheel control and the lower acceleration limits of the B-26 would result in a higher value of stick force per normal acceleration.

An optimum value of steady state pitching velocity per stick force, .47 degrees per second-pound, was determined in the investigation of Reference 8 for a short period natural frequency, ω, of 0.52 cps and a damping ratio, ζ, of 0.33. The pitching velocity gains indicated above for the B-26 and F-94 are approximately equidistant from this optimum value. If the fixed-base simulator results of Reference 8 are directly transferrable to in-flight simulation, then the difference in the values of this static gain between the B-26 and F-94 investigations should have little effect on pilot ratings. However, there are indications that the stick forces were somewhat high for frequencies of 0.6 cps and higher in this B-26 investigation. (See discussion of pilot comments in Section VII and particularly the long-look comments in Appendix D.) If the airplane response to pilot-applied stick force had been optimized for the B-26, better agreement with the F-94 data may have resulted at the higher frequencies.

A similar argument can be developed for the differences in the minimum frequency requirements for the 3.5 or minimum satisfactory boundaries. There were no indications by the B-26 pilots that stick forces were too light or too heavy in this region. A recurring comment was the apparent change in stick force as a result of attempts by the pilot to overdrive the response in order to speed it up. On the other hand the F-94 pilots (Reference 2) commented on the apparent high stick forces in this region.

In summary it appears that optimization of the static response gains with natural frequency in both the B-26 and F-94 tests would have resulted in better

over-all agreement of the results. Such optimization would have resulted in increasing acceleration (or pitching velocity) response per stick force input with increasing short period natural frequency. Evidence for such a change in response gain is evident in the results presented in Reference 8.

The boundary established in the fixed-base simulator results of Reference 8 does not allow for much direct comparison due to the different ranges of configurations that were evaluated. However, cautious extrapolation of the boundaries of Figure 16 would indicate good agreement with the data from Reference 8.

The original B-26 "poor" boundary is much more critical than the minimum acceptable boundary obtained in this investigation. This is particularly true in its exclusion of frequencies above 0. 6 cps and is attributed to the original variable stability equipment in the B-26. The servo natural frequencies were inadequately low for this range of dynamic characteristics. Also, the stick force per normal acceleration was much higher – 66 pounds per g – for the earlier B-26 investigation.

SECTION VII
PILOT COMMENT DATA

The pilot comments on each configuration are tabulated in Appendix D. The comments have been edited, but the wording used by the pilot has been retained as much as possible. The comment card served as a guide or outline for the commentary. Use of it insured that important items would not be overlooked, and also gave uniformity to the format of the comments, which was an aid in analyzing them. The short-look comments were about 100 words long, while the long-look comments consisted of about 500 words.

The pilot often commented upon what he had to do to make the airplane behave the way he wanted it to, rather than on how it behaved if left to itself. In other words, a pilot is more interested in the closed-loop performance than the open-loop performance. Alternatively, the comments can be described as input oriented, rather than output oriented. For example, given a configuration with light damping of the short period mode, the pilot may report stick force variations (heavy, lightens, then heavy again), but not comment explicitly on the oscillatory motion. He adds damping to produce a motion which is not oscillatory and comments on the pilot input required to produce that motion in a basically oscillatory airplane.

Pilot comments, extracted from the long-look data, are located on a grid of short period frequency and damping in Figure 18. The mean rating boundaries of Figure 16 are included. The comments explain why a given rating was assigned, or to put it another way, they show what aspects of the motion of a given configuration were the important ones. This information is valuable because the same rating may be applied to different configurations for quite different reasons. For example, configuration 6 (ω = .6, ζ = .2) and configuration 26 (ω = .3, ζ = .8) received the same mean rating although they are quite different. Configuration 6 was fairly easy to trim, and responded to the controls promptly, but poor damping made tracking difficult. Configuration 26, on the other hand, showed no tendency to bobble, and steady tracking was easy; but the rather low natural frequency made it difficult to shift the point of aim quickly or maneuver. The airplane tended to keep moving after the pilot expected the motion would stop, not in an oscillatory fashion due to poor damping, but because the low frequency gave a long response time, which the pilot was not able to predict accurately.

Another interesting example of the value of comments is given by configuration 28 (ω = .2, ζ = .5). This is a low frequency, reasonably well damped configuration, and might be expected to lead to comments such as "sluggish" or "slow to respond". These comments appear, but the major reason for the low rating assigned to it is the tendency for the pilots to produce an oscillation. The fact that the pilots find a sufficiently low frequency oscillation difficult rather than easy to control is important, and would not be apparent if only ratings were used. No attempt was made in this investigation to delineate the range of variables over which this low frequency pilot-induced oscillation may appear.

Comparison of Long-Look and Short-Look Comments

The additional time spent on each configuration could be expected to produce better comment data from the long-look evaluation and in fact, it does. The difference in quality and detail in the comments depends somewhat upon the configuration. The short-look comments contain essentially as much information as the long-look comments for configurations with high frequency or low damping, as for example, pilot A, configurations 5 and 14. However, pilots often have difficulty in pinning down exactly what is bothering them in some configurations, and talk all around the problem. The longer evaluation time of the long look helps the pilot to formulate his ideas, and the more copious comments help the analyst to detect what aspect of the motion is important to the pilot. The comments of pilot C on configuration 16 are a good example. In the short look he knew something was not good, but could not identify it, while the long look enabled him to describe the trouble more explicitly.

Generally speaking, the lower frequencies gave the pilots more trouble in analyzing the motion, and it is in these frequencies that the differences between long-look and short-look comments show up most clearly, especially in the description of the response of the airplane while obtaining and holding a given normal acceleration. Compare, for example, the comments of pilot A on configuration 26 or 28. The long-look comments of pilot B for configurations 7, 12, 17, 22, 26, and 28 all show considerably more detail in describing the character and desirability of the response. The long-look comments on marginal configurations are generally better, such as those of pilot A for configurations 23 and 28.

The short-look comment data is surprisingly good in its detail and consistency, considering the amount of time the pilot was allowed to spend on each configuration. However, the additional detail and the better understanding exhibited in the long-look comments makes them more useful in an investigation of an unknown or troublesome group of handling qualities.

SECTION VIII
CONCLUSIONS

An investigation has been conducted of two methods for flight research on flying qualities requirements. This investigation, using a variable stability airplane, was confined to longitudinal characteristics only. One method involved a small number of pilots using essentially unlimited evaluation time (long look) while the other involved a short fixed evaluation period with a large group of pilots (short look). Pilot rating (PR) data obtained by the two methods have been examined by statistical analysis techniques, and by comparison results in terms of well known flying qualities boundaries. Pilot comments have been used wherever possible to gain further understanding of the results. This investigation leads to the following conclusions.

<u>Comparison of Short-Look Versus Long-Look Test Methods</u>

1. For flying qualities research, the long-look evaluation is superior. It provides a truer evaluation of the effects of various parameters on pilot ratings because the pilot has time to search for undesirable effects, to learn to cope with peculiarities in the flying qualities and to exploit the good features. The long look improves the quality of pilot comment data since it allows sufficient time for the pilot to formulate his ideas and express them clearly.

   Data from the long-look evaluation provides a more accurate quantitative mapping of pilot ratings, particularly in establishing a "minimum satisfactory" boundary (PR = 3.5). However, short-look and long-look data both produced the same "minimum acceptable" boundary (PR = 6.5). A "minimum acceptable" rating appears to be a relatively well-defined rating and the short look allowed the pilot adequate time for a sound rating. The "minimum satisfactory" rating appears to be more elusive, and the additional time of the long look produced a change in pilot rating compared to the short look. The long-look boundary is considered a more truly representative boundary.

2. The short-look evaluation, using many pilots, shows the magnitude of interpilot variability. After the interpilot variability has been determined, there is little incentive to use the short-look evaluation method, because the long look produces superior data.

3. The effect of increased evaluation time (long look) was generally to improve ratings for satisfactory configurations and to lower the ratings for basically poor ratings.

<u>Variability of Pilot Ratings</u>

1. As concluded above, the data did show a difference, for certain ranges of pilot rating, between the short- and long-look ratings of the pilots who performed both evaluations. The pilots who

performed the long-look evaluation were shown to be representative of the group of short-look pilots. There is some small probability that the observed differences could be caused by chance sampling effects. This probability is considered small enough to warrant the above conclusions.

2. For both methods, the range of rating differences was large, but the standard deviation due to pilots was reasonably low (PR = 0.7). This interpilot variability was somewhat less than the intrapilot variability which showed a standard deviation of approximately PR = 1.0. However, due to the relatively small number of repeat configurations used in these tests, the intrapilot variability is not as precisely defined. To put it simply, the data shows that pilots agree with one another about as closely as any one pilot agrees with himself for repeated trials.

3. The range of rating differences between pilots shows a need for a minimum number of pilots even for long-look evaluations. The results of this investigation suggest a minimum number of three pilots to be satisfactory. If circumstances require use of only one pilot, the data may not be representative although the chances are that it will be. If at all possible, care should be taken to make sure that he is representative of a large group of pilots.

Effect of Frequency and Damping on Pilot Rating

While not a specific part of this investigation, certain effects of frequency and damping on the pilot ratings are observed:

1. Pilot ratings show an optimum frequency near 0.5 cps for longitudinal short period motion. This frequency is chosen as optimum regardless of damping ratio.

2. Pilots rate the longitudinal short period motion increasingly acceptable as the damping ratio is increased up to a damping ratio of approximately $\zeta = .5$. Above this damping ratio, there is little further improvement with increasing damping ratio.

Evaluation of Flying Qualities of a Specific Airplane

While this program examined only the area of flying qualities research, the results have application to the evaluation of a specific airplane design with regard to the suitability of its stability and control characteristics. Evaluation by a small number of pilots (perhaps only one or two) will allow the pilot time to fully evaluate the airplane's characteristics, to learn how best to treat any unusual characteristics, and to develop a clear understanding and explanation of them. Short evaluations by a larger group of pilots can then confirm the findings or reveal differences, based on interpilot variability or differing pilot technique, which will require further evaluation. A small group, using short-look evaluations, is not recommended, for it provides neither the benefits of

a searching look by any pilot nor the statistical reliability and accounting for interpilot variability.

Limitations of Investigation

Boundaries between acceptable and unacceptable longitudinal short period handling qualities, presented in this report, apply for a set of tasks which involve precise maneuvering of the airplane. They were obtained for only one value of the numerator of the transfer function of the airplane. Investigation of changes in the boundaries for different values of the numerator (which is affected by airspeed and slope of the lift curve) was beyond the scope of the investigation.

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TABLE I

MANEUVERS

A. Trim in level flight for at least one minute.

Note:
1. Ability to trim at desired airspeed.
2. Ability to remain in trim.
3. Any oscillatory motion.

B. Make abrupt control steps to +1.5 g, 2.0 g and 0.5 g absolute acceleration. Note airplane response time and any oscillatory motion.

C. Make slow and rapid entries into level turns, holding sight on horizon. Continue turns for at least 180°, noting relative ease and accuracy of tracking the horizon with elevator control.

D. Slow airplane to 180 mph, push over on ground target (dive angle about 20°) and stay on target until speed reaches 240 mph. Note relative ability to get on target quickly and accurately, and ability to maintain load factor during recovery.

TABLE II

SHORT-LOOK COMMENTS

1. Ability to trim
2. Stick force
   Initial part of motion
   Steady part of motion
3. Airplane response to control
4. Ability to reach and maintain desired g.
5. Longitudinal motion in entry and recovery from turn
6. Ability to track in turn and dive
7. Response in push-over and pull-up
8. General feel of airplane

TABLE III

LONG-LOOK COMMENTS

MANEUVER A:

1. Ability to trim
2. Stick force
3. Airplane response to control (time and motion)
4. Feel of airplane

MANEUVER B:

1. Stick force
   Initial
   Final
2. Stick motion
3. Airplane response to control (time and motion)
   Initial
   Final
4. Ability to reach and maintain desired g
5. Feel of airplane

MANEUVER C:

1. Stick forces
   Entry and recovery
   Steady turn
2. Stick motion
3. Airplane longitudinal response to control
   Entry and recovery
   Steady turn
4. Ability to track
5. Feel of airplane

MANEUVER D:

1. Stick force
   Push-over
   Tracking
   Pull-out
2. Stick motion
3. Airplane response to control (time and motion)
   Push-over
   Tracking
   Pull-out
4. Ability to push over and get on target
   Ability to track target
   Ability to hold "g" during pull-out
5. Feel of airplane and controls.

TABLE IV

RATING SCALE

Numerical Rating	Category	Adjective Description Within Category
1	Acceptable and Satisfactory	Excellent
2		Good
3		Fair
4	Acceptable but Unsatisfactory	Fair
5		Poor
6		Bad
7	Unacceptable	Bad
8		Very Bad
9		Dangerous
10	Unflyable	

TABLE V LIMITED EVALUATION PILOT RATING DATA

			PILOTS															Mean Ratings		
Conf.	Freq.	Damp.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	All Pilots	Less Pilot O	Less Pilots B, F, G H, O
1	.8	.2	6	7	6	7	7	5	8	6	6	4	5	6	2	7	6	5.86	5.86	5.60
2		.3													1		5			
3		.5	4	7	5	4	3	5	2	7	5	5	9	2	1.5	4		4.54	4.54	4.25
4	.7	.4													2		6			
5	.6	.2	5	7	6	4	6	4	4	7	6	4	6	2	3	3.5		4.83	4.83	4.55
6		.3	4	4	2	2	4	3	7	5	3	4	2.5	3	4	3		3.60	3.60	3.15
7		.5	1	4	1	3	4	3.5	3	3	4	2	3	2	2	1.5	3	2.66	2.64	2.35
9	.5	.2	5	7	5	8	2	5	7	3	5	3	2	6	4	4	4	4.66	4.71	4.40
11		.3													3					
12		.4	2	4	2	2	1	4	4	5	4	4	2	1	2	2.5	4	2.90	2.82	2.25
13		.6															2			
14	.4	.1	7	8	5	7	8	8	9	9	6	7	8	7	7	7		7.36	7.36	6.90
15		.2	4	5	2	5	5	7	8	6	6	4	6	7	5	6	3	5.26	5.42	5.00
16		.3	2	4	3	4	1	5	7	5	4	4	2	5	3	2.5	4	3.70	3.68	3.05
18		.4													3		2			
19		.5	2	3	1	3	4	3	2	7	3	2	2	7	3	3	3	3.20	3.21	3.00
21		.7															2			
22	.3	.2	6	7.5	7	6	7	8.5	8	8	6	6	7	7	7	5.5		6.90	6.90	6.45
23		.4	3	5	3	2	4	4	7	7	5	4	2	7	3	3		4.21	4.21	3.60
26		.8	2	8	2	4	3	6	3	3	5	5	1	6	3	3	6	4.0	3.86	3.4
27	.2	.3		7	7	8	9	9	9	9	8	6	7	8	8	9	5	7.8	8.00	7.77
28		.5	7	7	7	8	8	7	9	9	7	9	6	7	6	9		7.58	7.58	7.4

TABLE VI

UNLIMITED EVALUATION PILOT RATING DATA

Conf.	Freq.	Damp.	Pilots A	Pilots B	Pilots C	Mean Ratings: All Pilots	Mean Ratings: Pilots A and C Only
1	.8	.2	6	3	4	4.33	5
2		.3	2	4	5	3.67	3.5
3		.5	2	2	2	2	2
4	.7	.4	1	4	4	3	2.5
5	.6	.2	4	7	5	5.33	4.5
6		.3	3	6	2	3.67	2.5
7		.5	3	4	2	3	2.5
8		.5	1	2	2	1.67	1.5
9	.5	.2	4	5	4	4.33	4
10		.2	4	5	5	4.67	4.5
11		.3	4	3	2	3	3
12		.4	1	4	2	2.33	1.5
13		.6	1	2	1	1.33	1
14	.4	.1	6	8	8	7.33	7
15		.2	7	6	8.5	7.17	7.75
16		.3	3	4	3	3.33	3
17		.3	4	6	3	4.33	3.5
18		.4	2	5	2	3	2
19		.5	2	3	2	2.33	2
20		.5	1	4	2	2.33	1.5
21		.7	1	2	2	1.67	1.5
22	.3	.2	6	9	7	7.33	6.5
23		.4	4	2	1	2.33	2.5
24		.4	2	4	3	3.0	2.5
25		.5	2	5	4	3.67	3
26		.8	3	7	2	4	2.5
27	.2	.3	8	9	8	8.33	8
28		.5	6	10	8	8	7
29		.5	6	8	7	7	6.5
30		.7	7	8	8	7.67	7.5

TABLE VII
PILOT RATING STANDARD DEVIATIONS

Configuration	Short-Look Standard Deviation Pilots A-N	Long-Look Standard Deviation Pilots A-C
1	1.51	1.53
2		1.53
3	2.12	0
4		1.73
5	1.54	1.53
6	1.30	2.09
7	1.06	1.73
8		.58
9	1.86	.58
10		.58
11		1.0
12	1.30	1.53
13		.58
14	1.08	1.16
15	1.50	1.26
16	1.57	.58
17		1.53
18		1.73
19	1.76	.58
20		1.53
21		.58
22	.90	1.53
23	1.76	1.53
24		.58
25		1.53
26	1.92	2.65
27		.58
28	1.09	2.0
29		1.0
30		.58

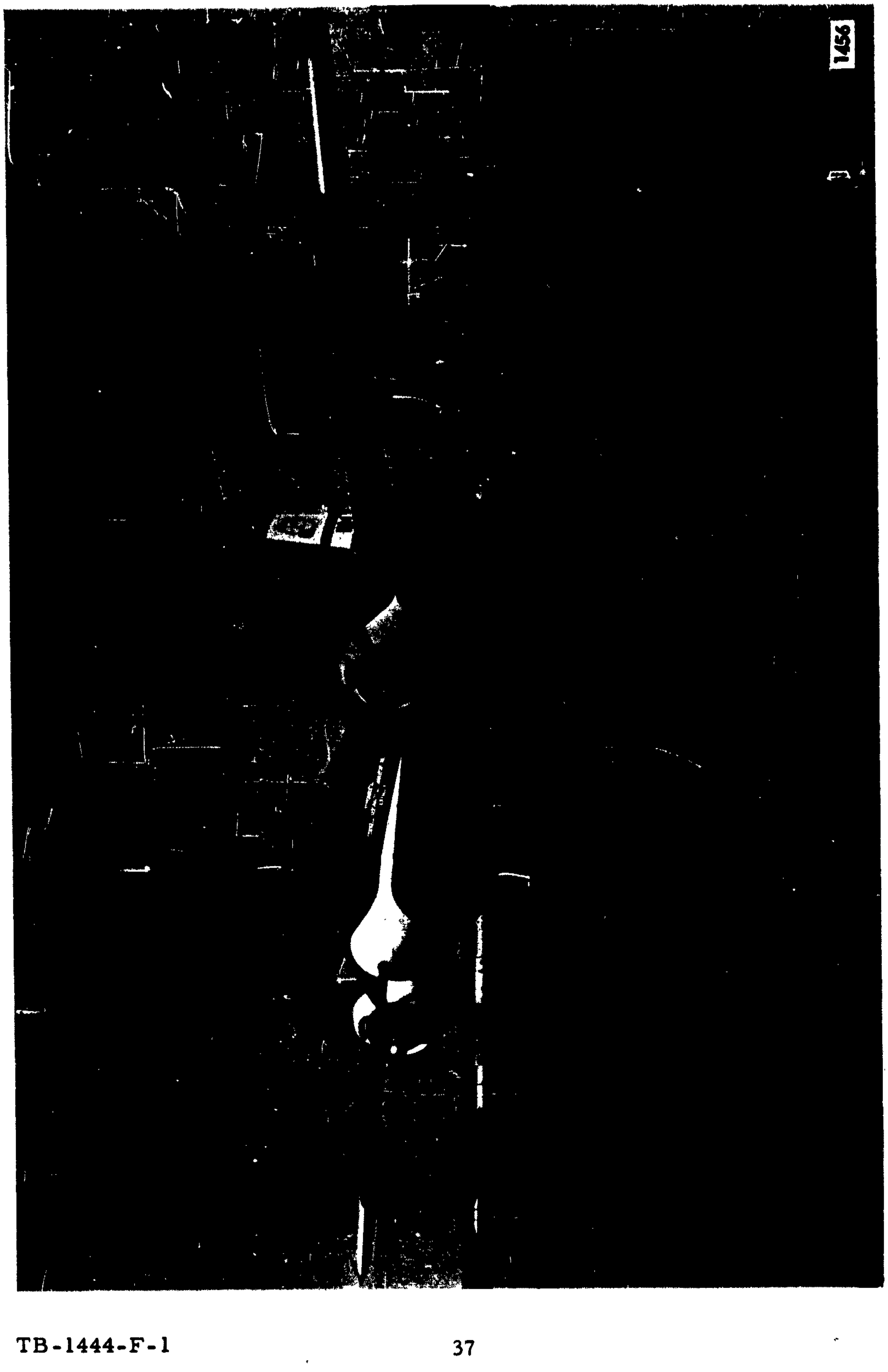


FIGURE 1 CORNELL AERONAUTICAL LABORATORY VARIABLE STABILITY B-26

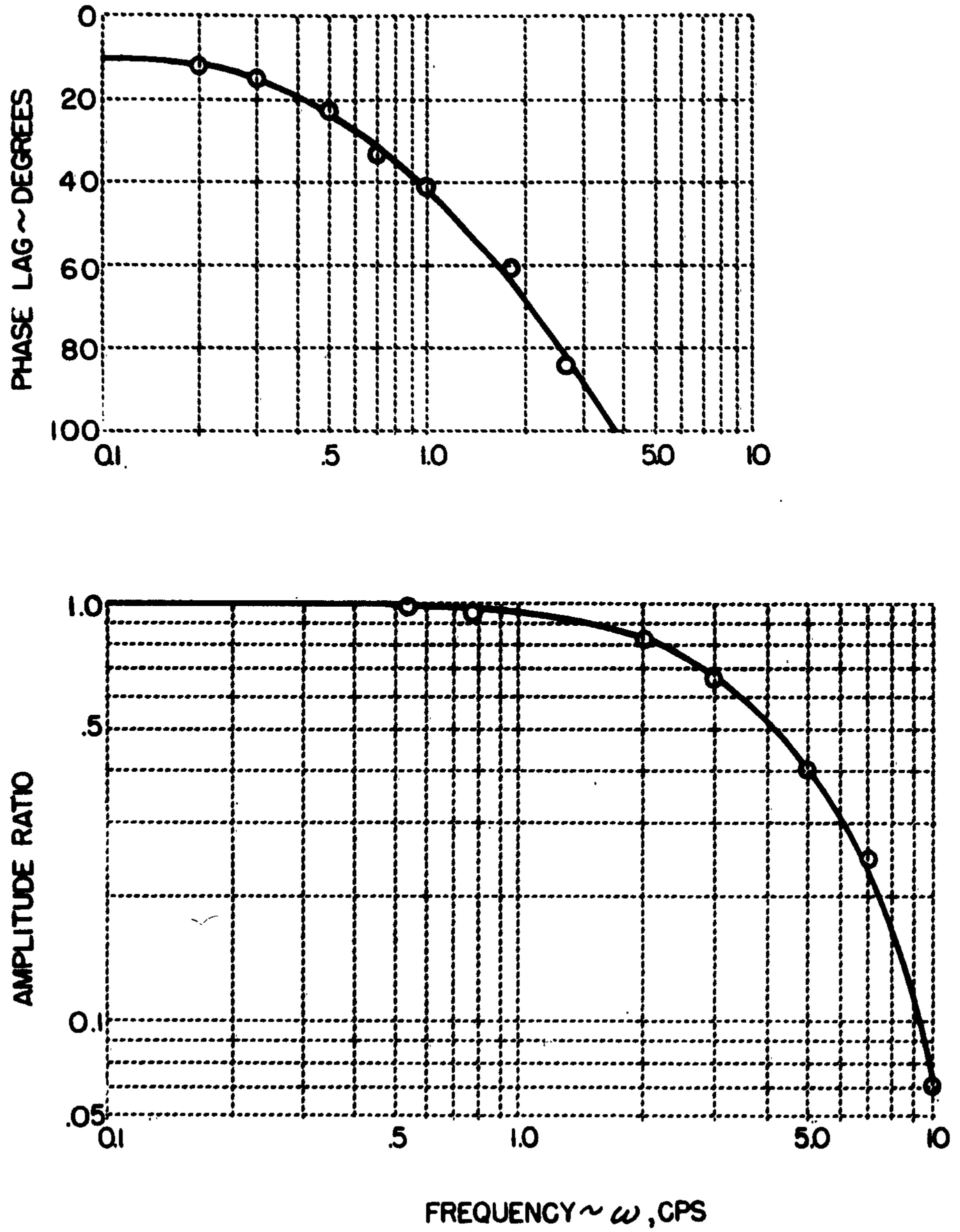


FIGURE 2 ELEVATOR SERVO FREQUENCY RESPONSE

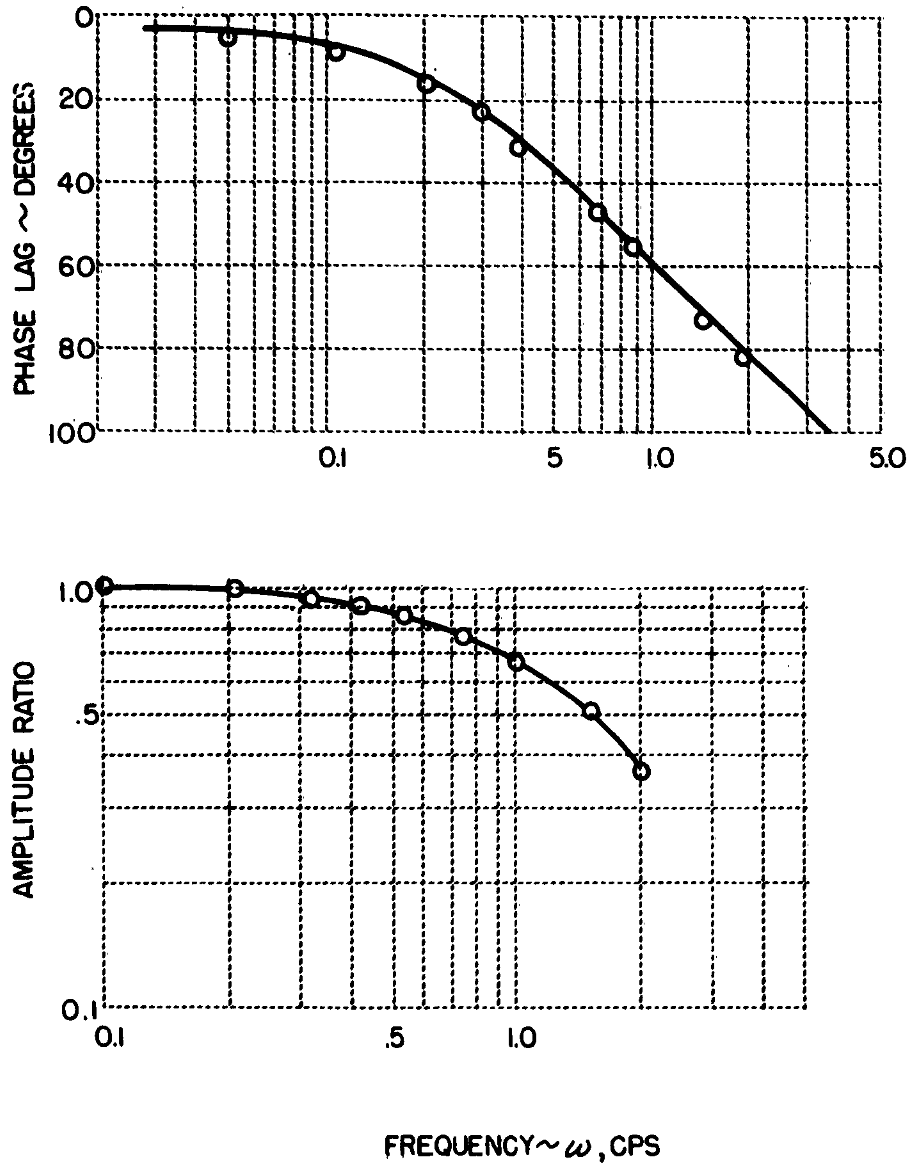


FIGURE 3 STICK SERVO FREQUENCY RESPONSE

● Evaluation Points - Short Look and Long Look, 16 Configurations

o Evaluation Points - Added for Long Look

O Repeat Evaluation Points - Long Look

(Numbers serve to identify points in Tables V and VI).

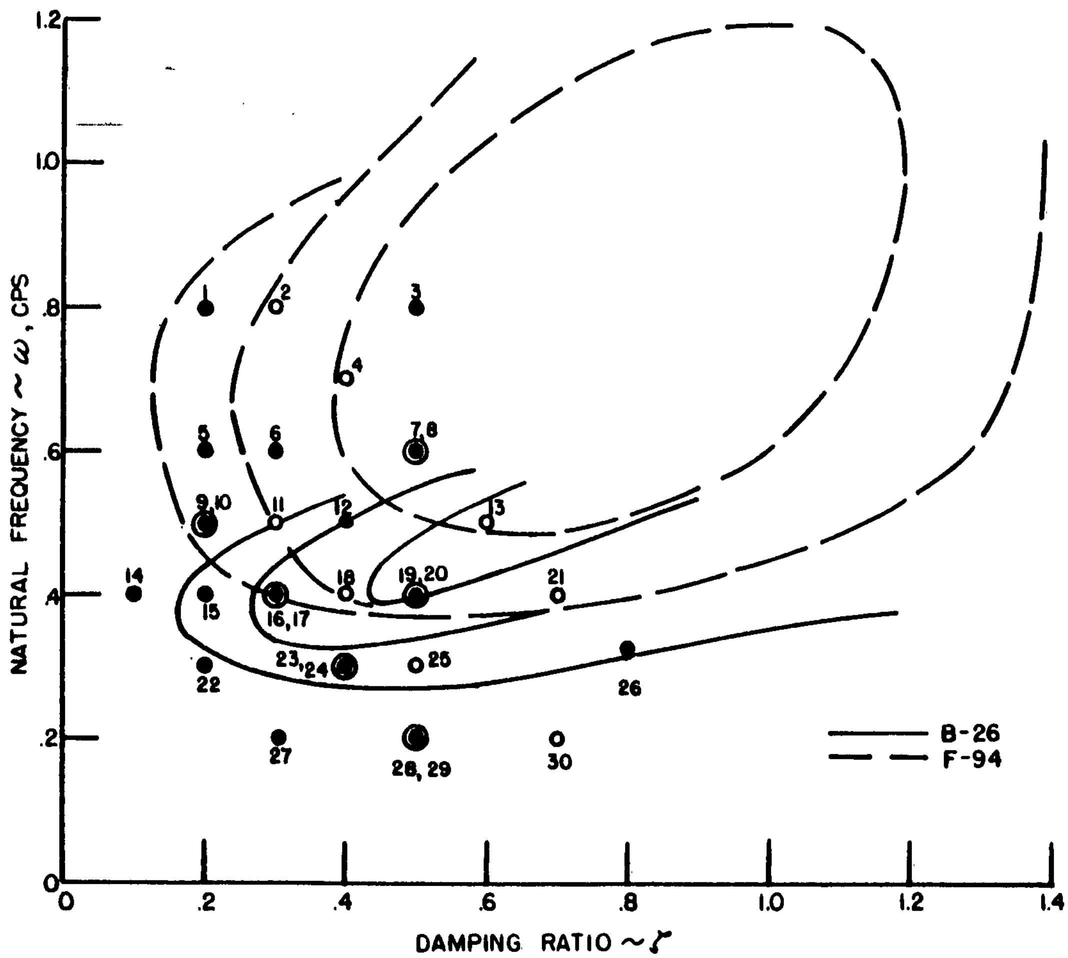


FIGURE 4 TEST CONFIGURATIONS

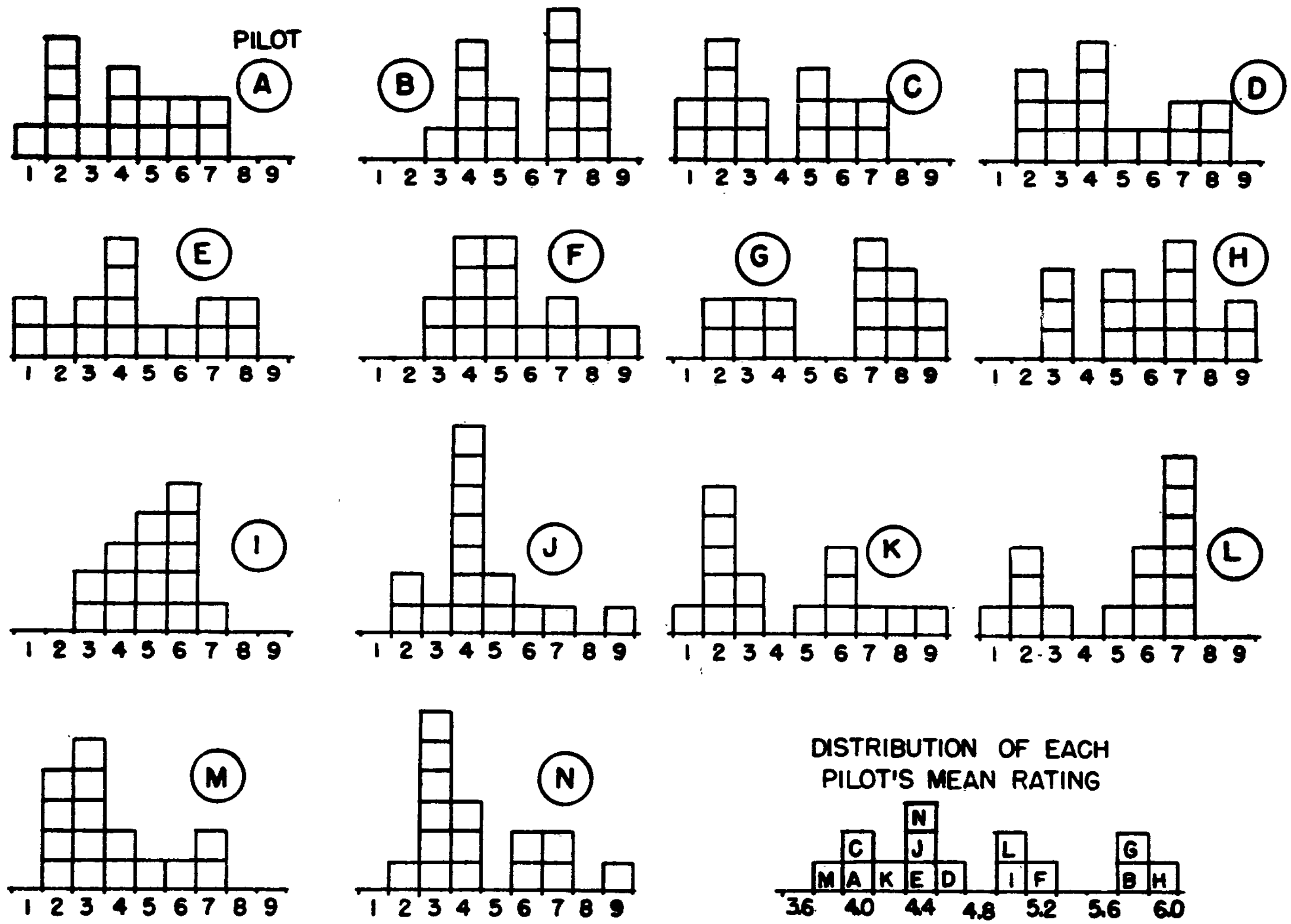


FIGURE 5 RATING DISTRIBUTIONS FOR EACH PILOT
LIMITED EVALUATION TIME

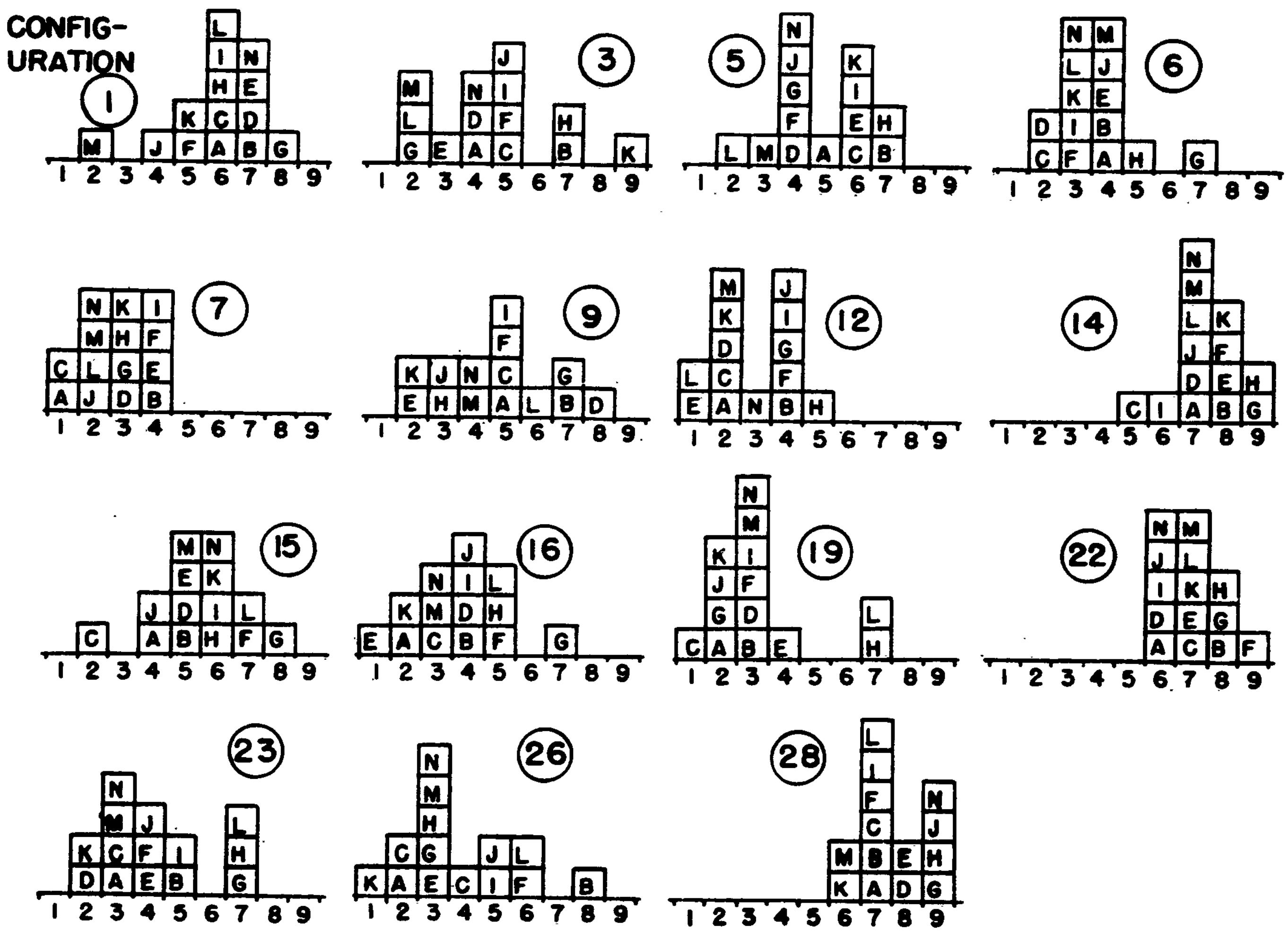


FIGURE 6 RATING DISTRIBUTIONS FOR EACH CONFIGURATION
LIMITED EVALUATION TIME

	Correlation Coefficient, r
All Data	-.20
Above 4.3 Rating	-0.90 (significant at .01 probability)
Below 4.3 Rating	0.73 (not significant)

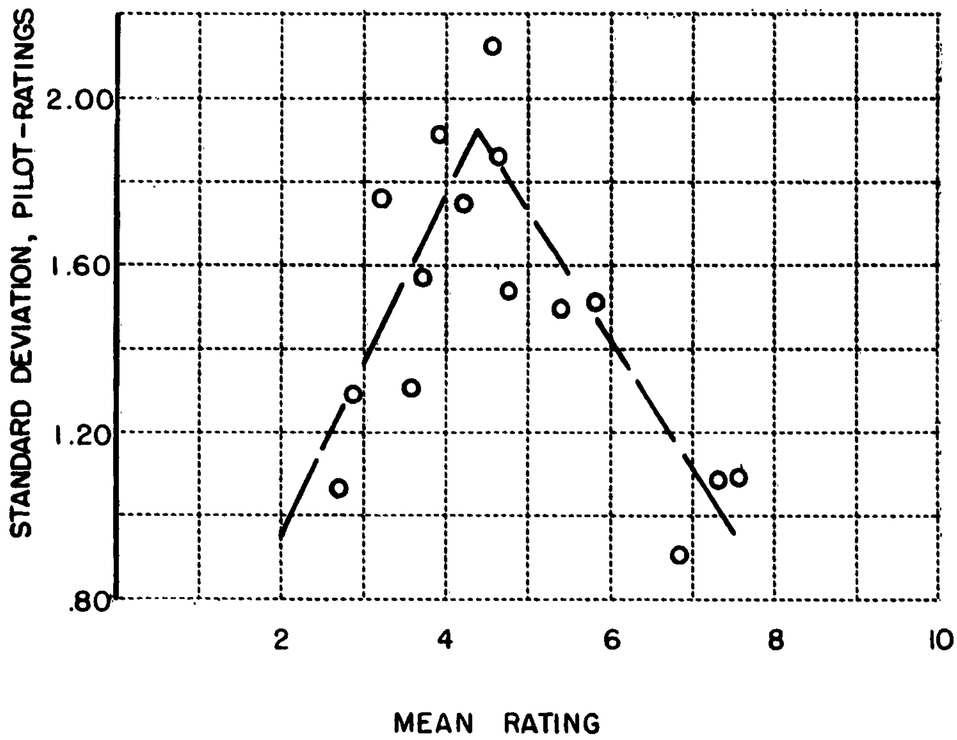


FIGURE 7 STANDARD DEVIATIONS AMONG PILOTS VS. MEAN RATING LIMITED EVALUATION TIME, PILOTS A-N

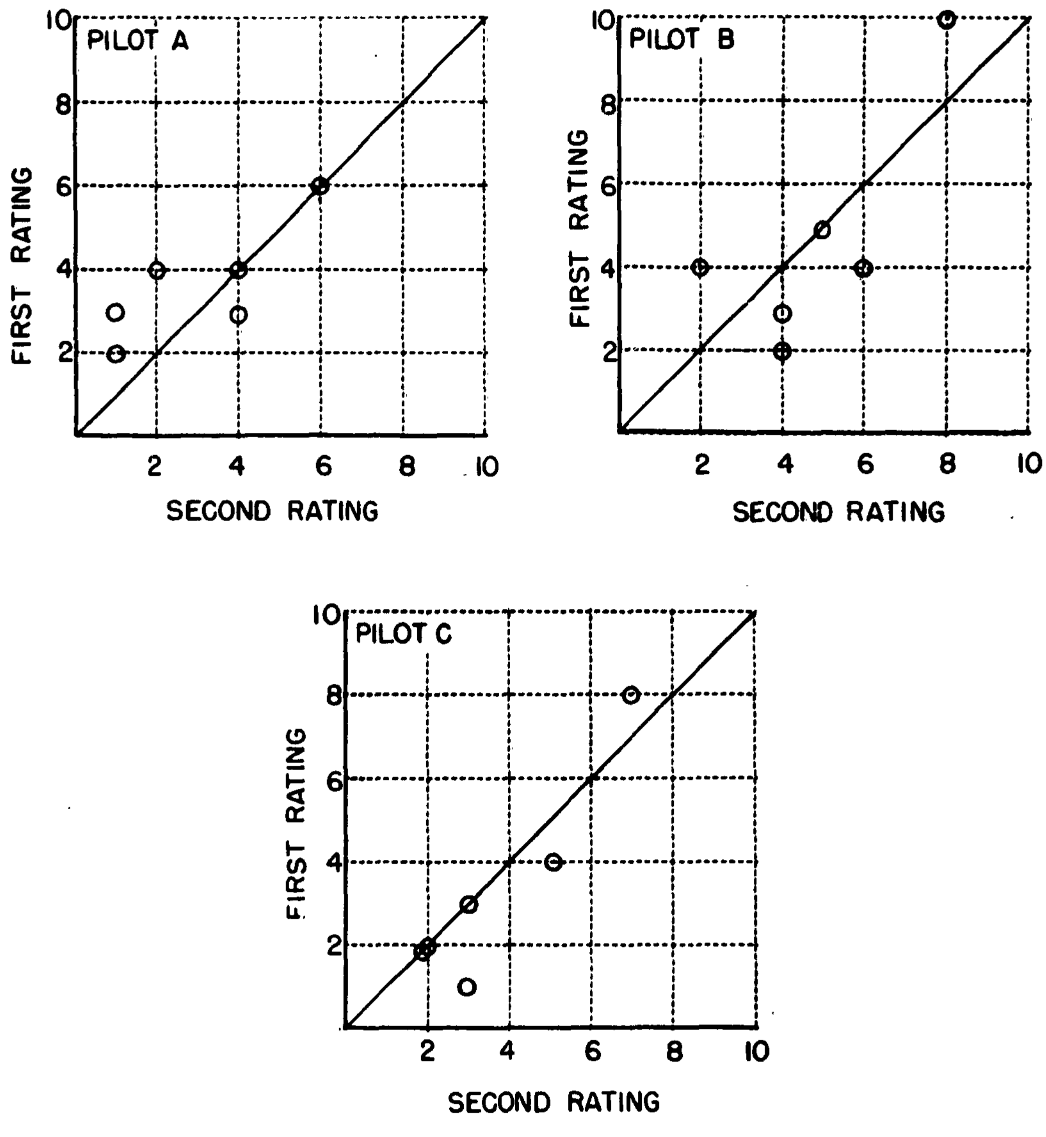


FIGURE 8 LONG-LOOK REPEATS, EACH PILOT

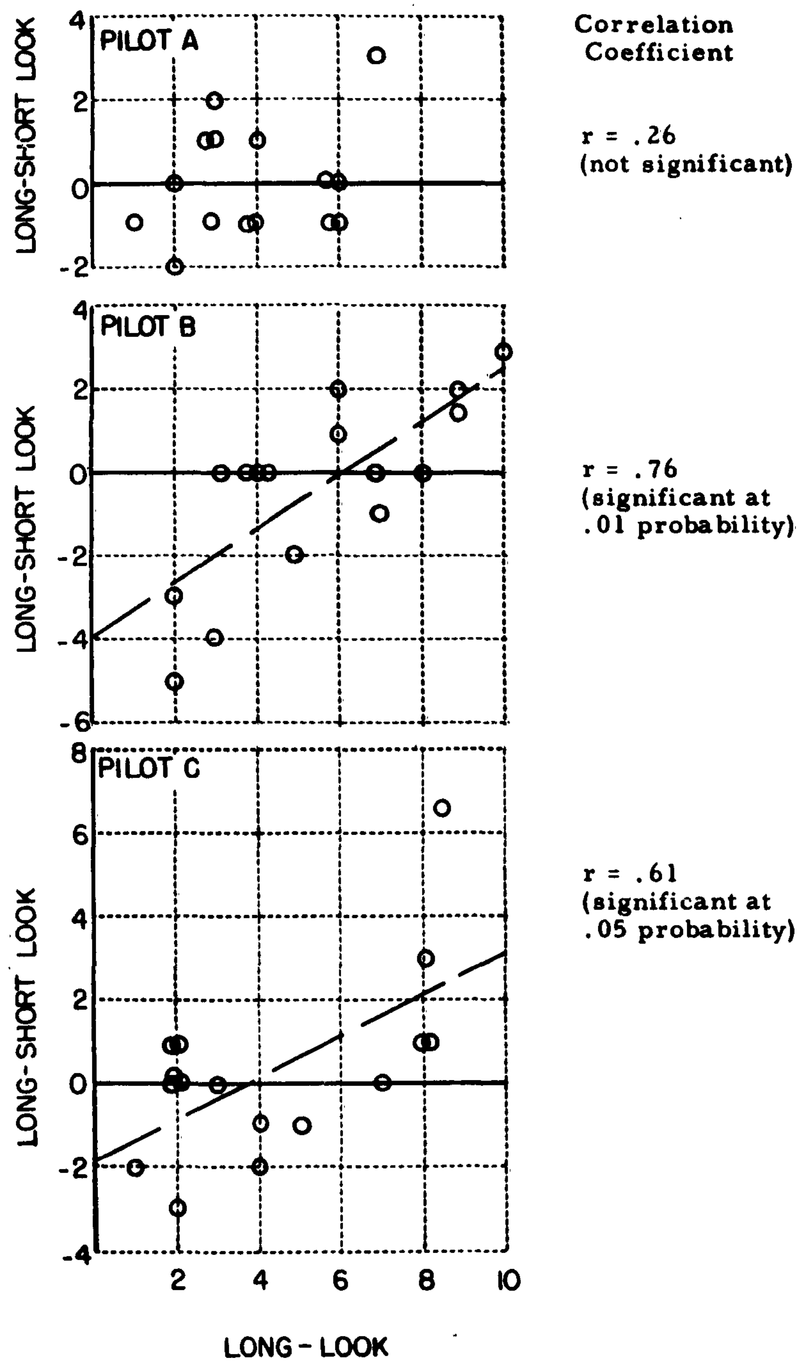


FIGURE 9 LONG-LOOK MINUS SHORT-LOOK VS. LONG-LOOK

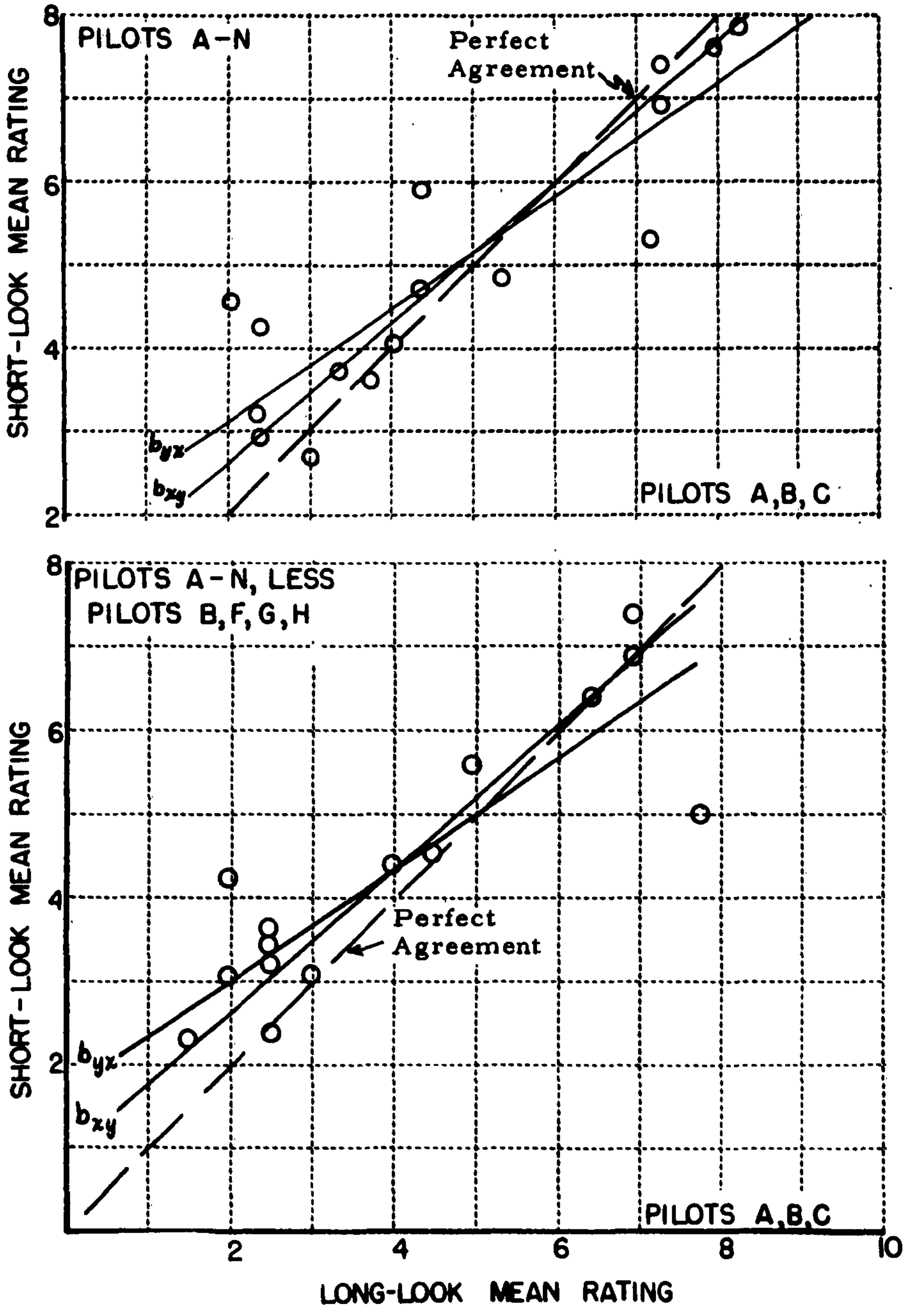


FIGURE 10 SHORT-LOOK MEANS VS. LONG-LOOK MEANS

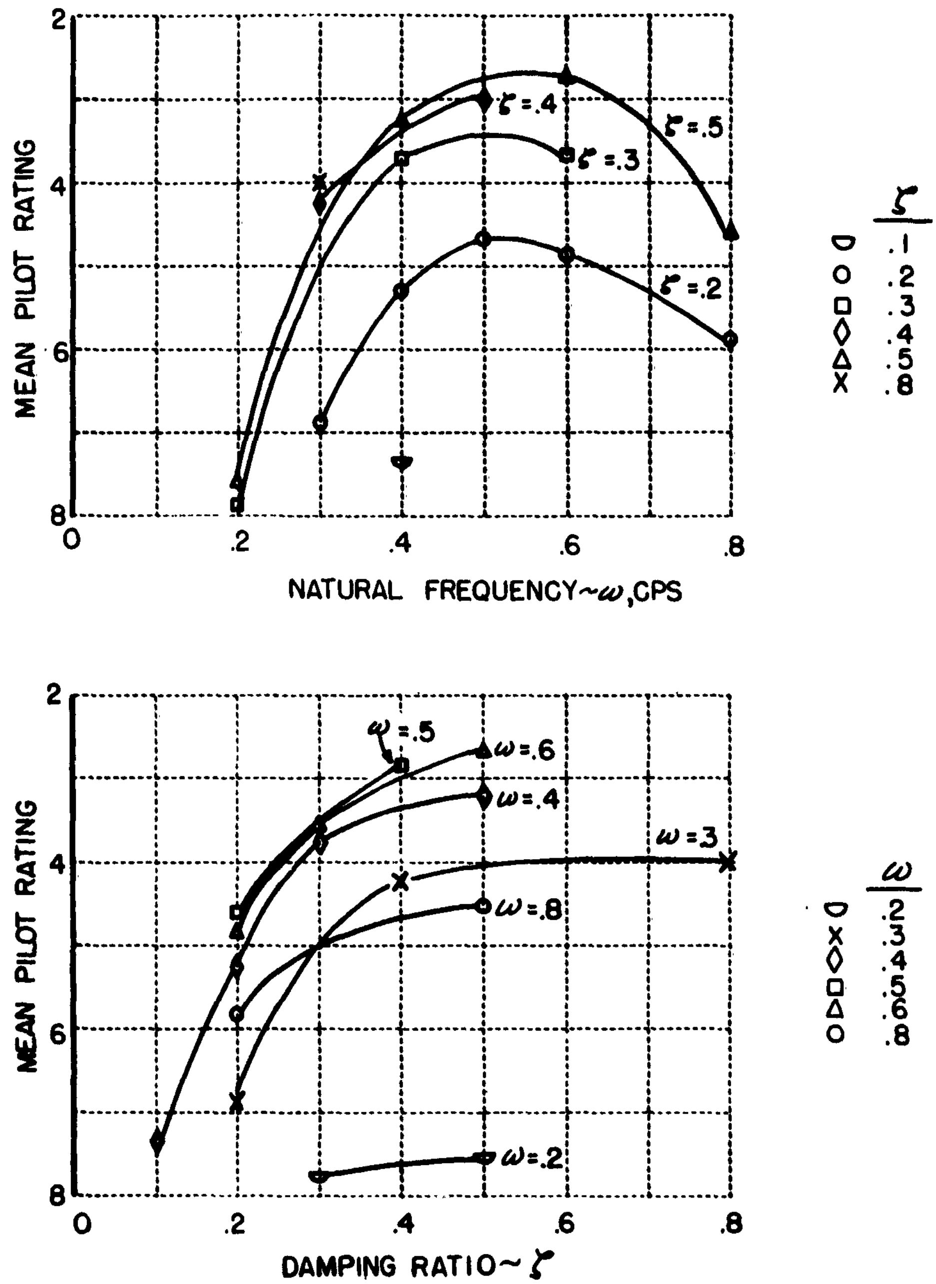


FIGURE 11 SHORT-LOOK RATINGS VS. ζ AND ω - ALL PILOTS

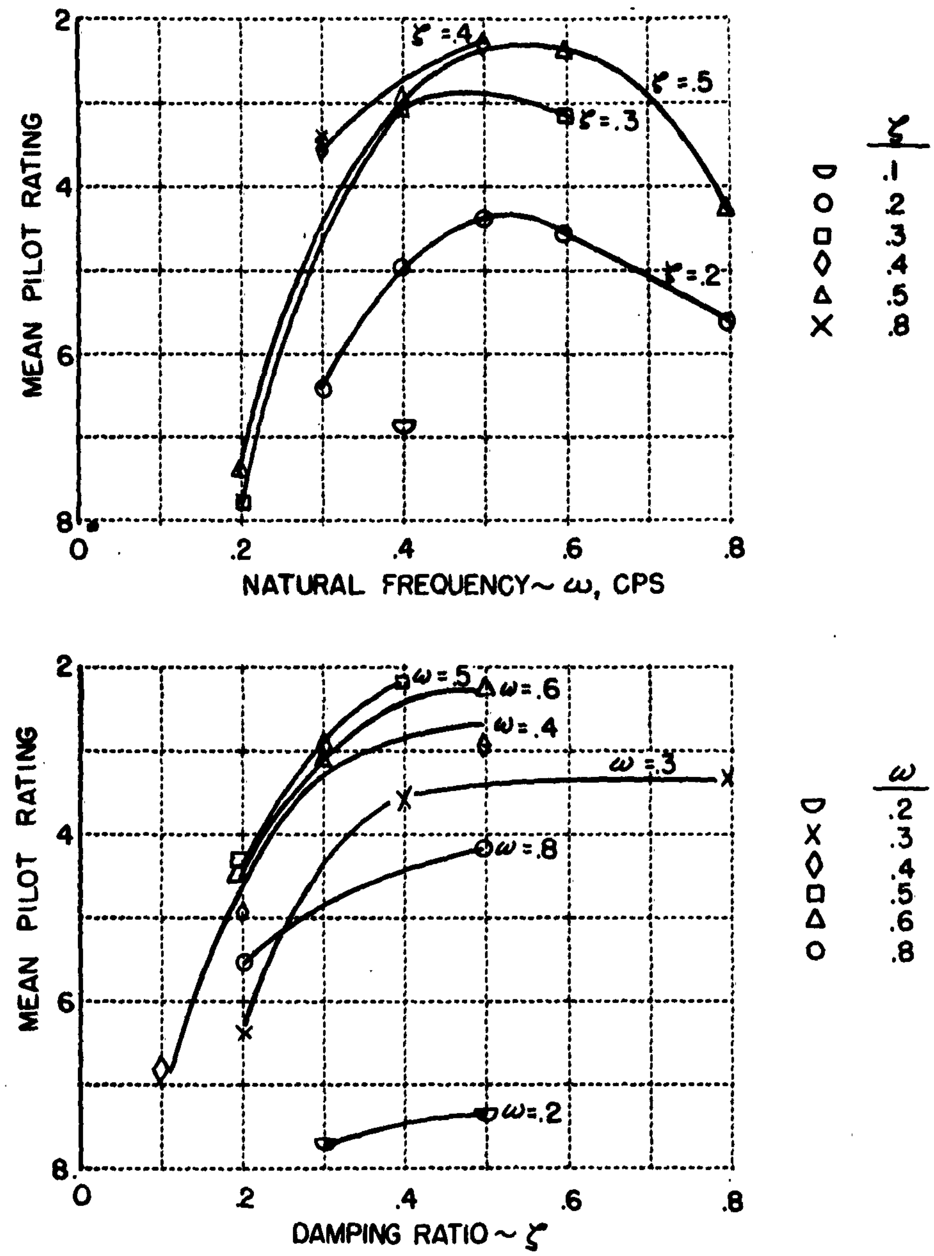


FIGURE 12 SHORT-LOOK RATINGS VS. ζ AND ω
LESS PILOTS B, F, G, AND H

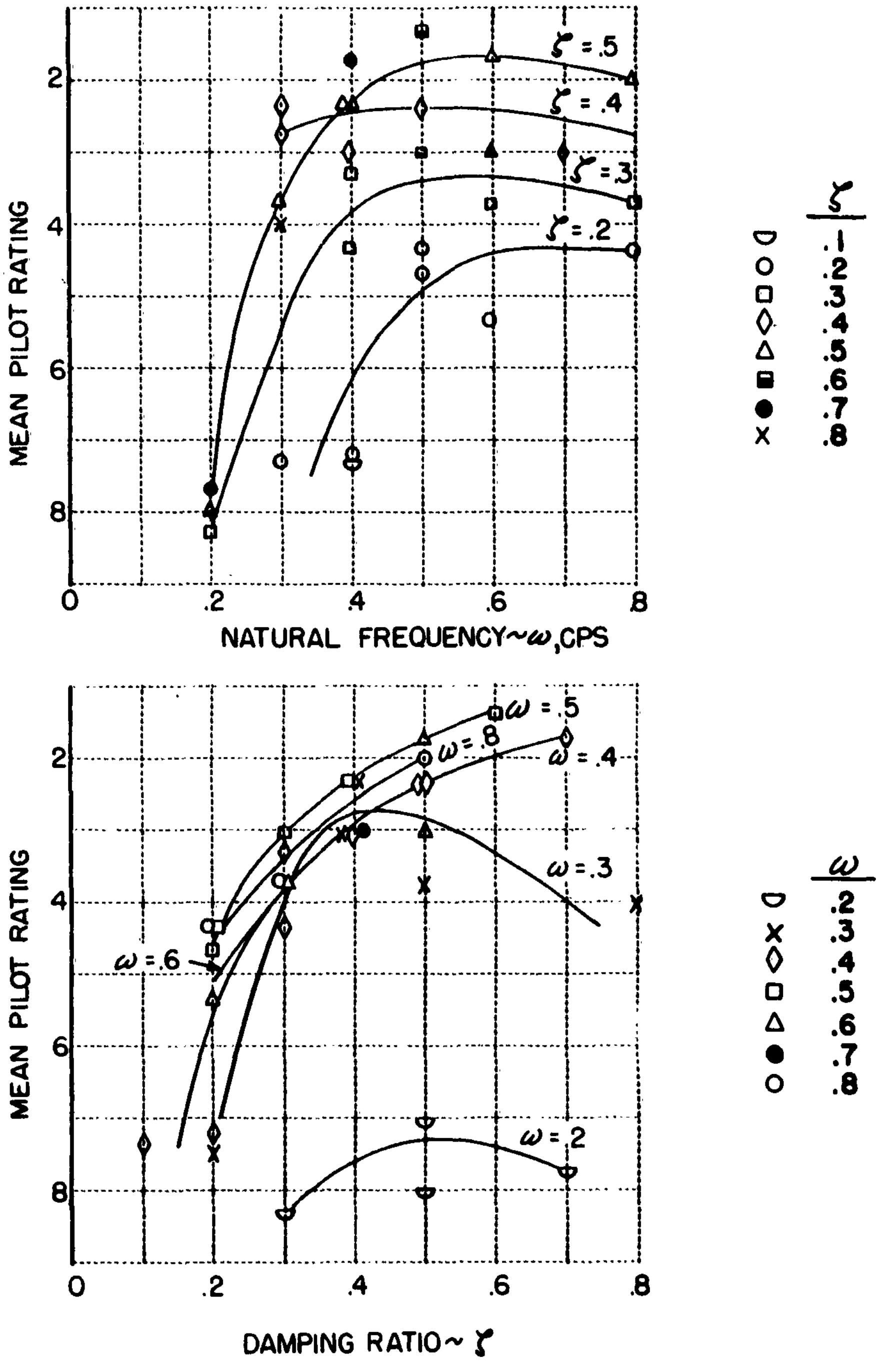


FIGURE 13 LONG-LOOK RATINGS VS. ζ AND ω - PILOTS A, B, AND C

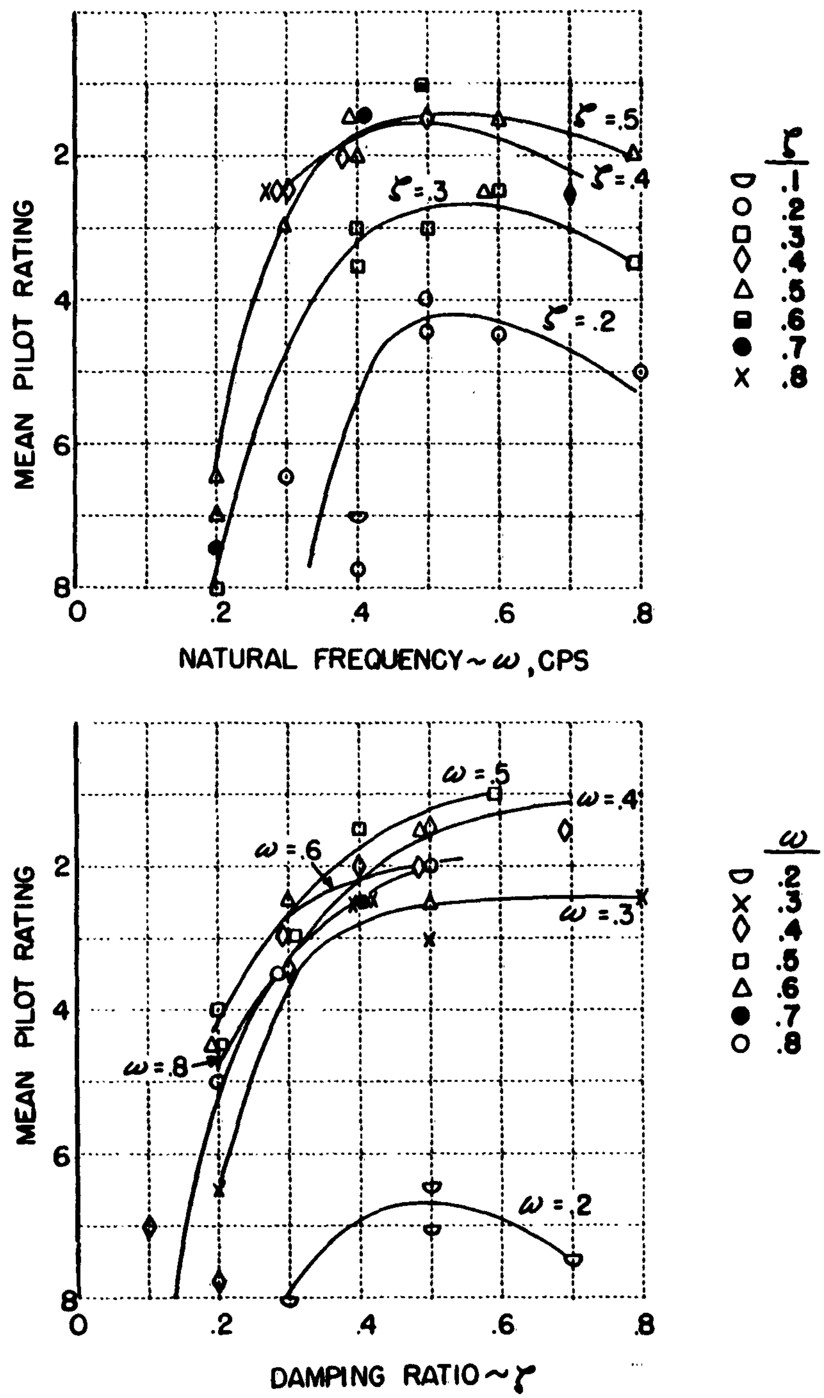


FIGURE 14 LONG-LOOK RATINGS VS. ζ AND ω - PILOTS A AND C

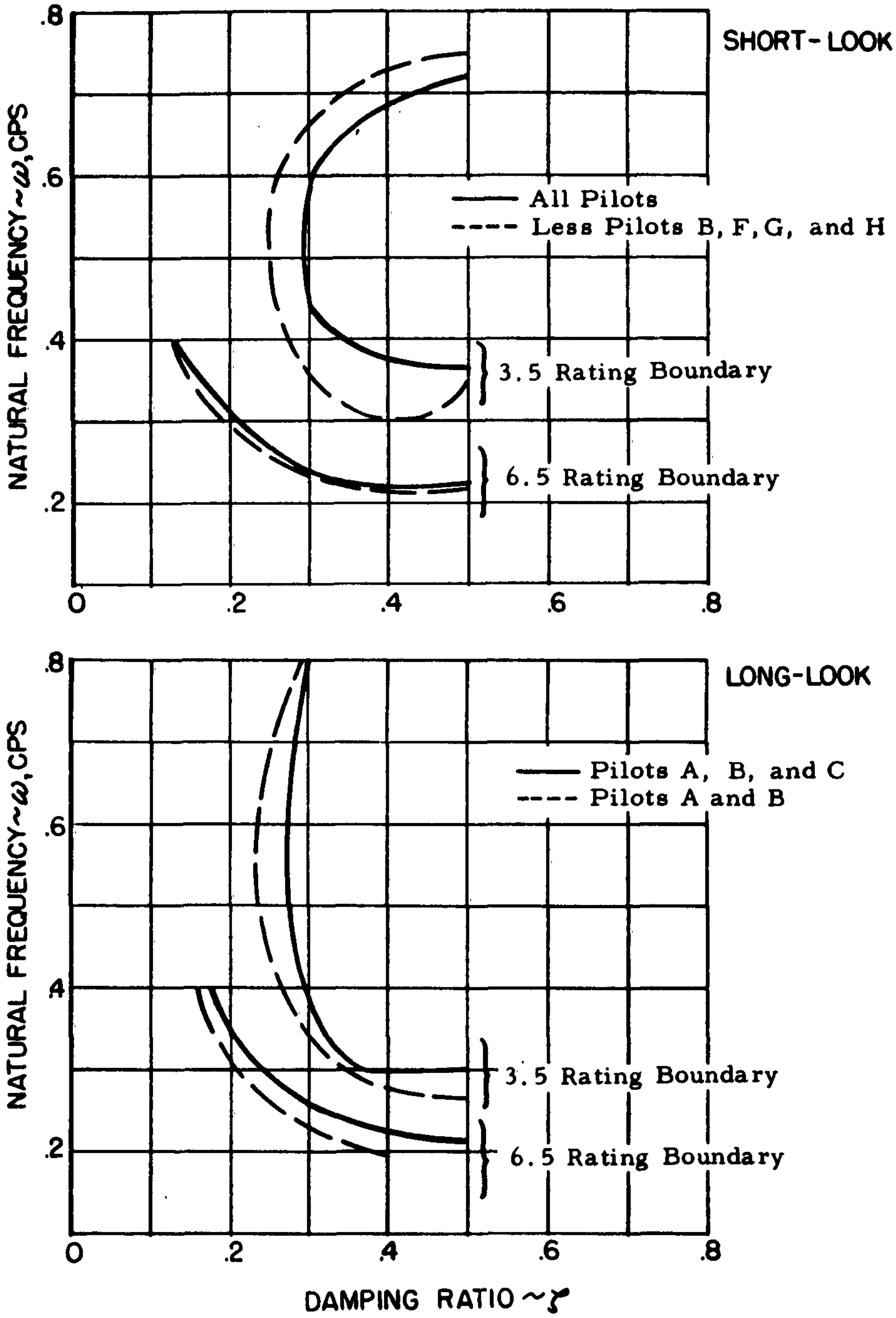


FIGURE 15 PILOT RATING AS FUNCTION OF ζ AND ω WITH 3.5 AND 6.5 BOUNDARIES

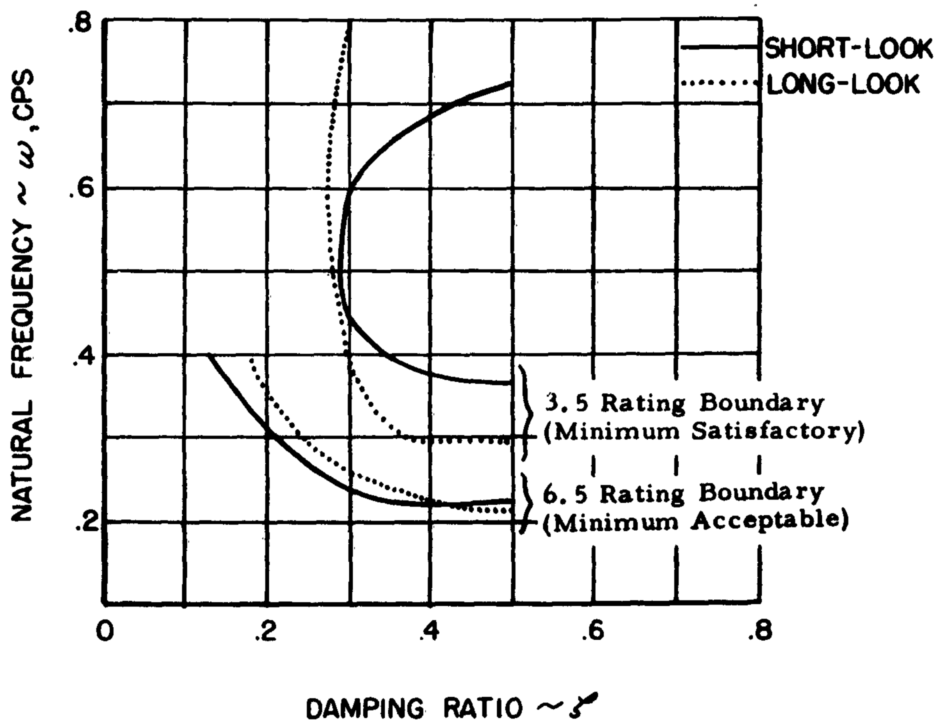


FIGURE 15a COMPARISON OF SHORT-LOOK AND LONG-LOOK BOUNDARIES (DATA OF FIGURE 15)

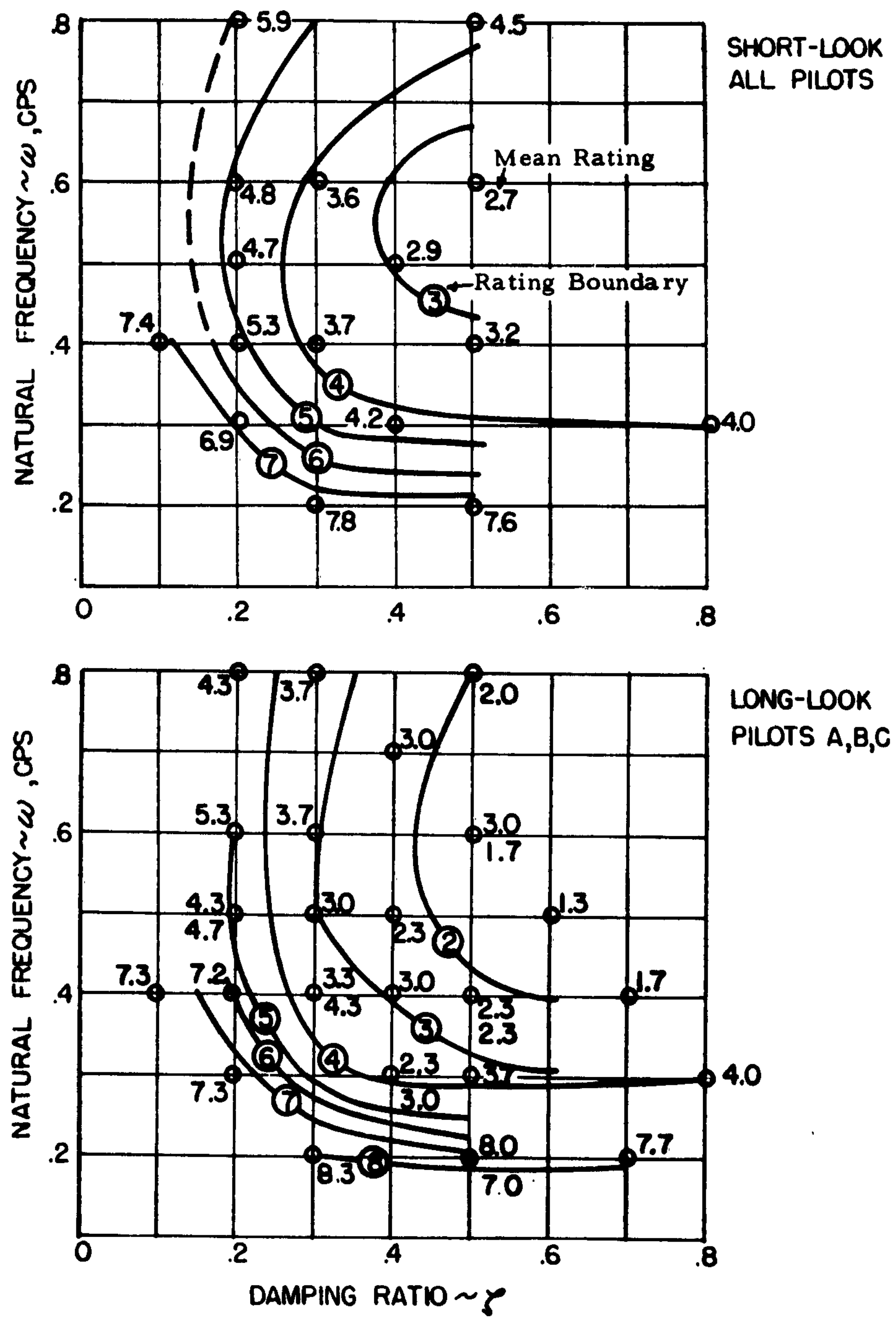
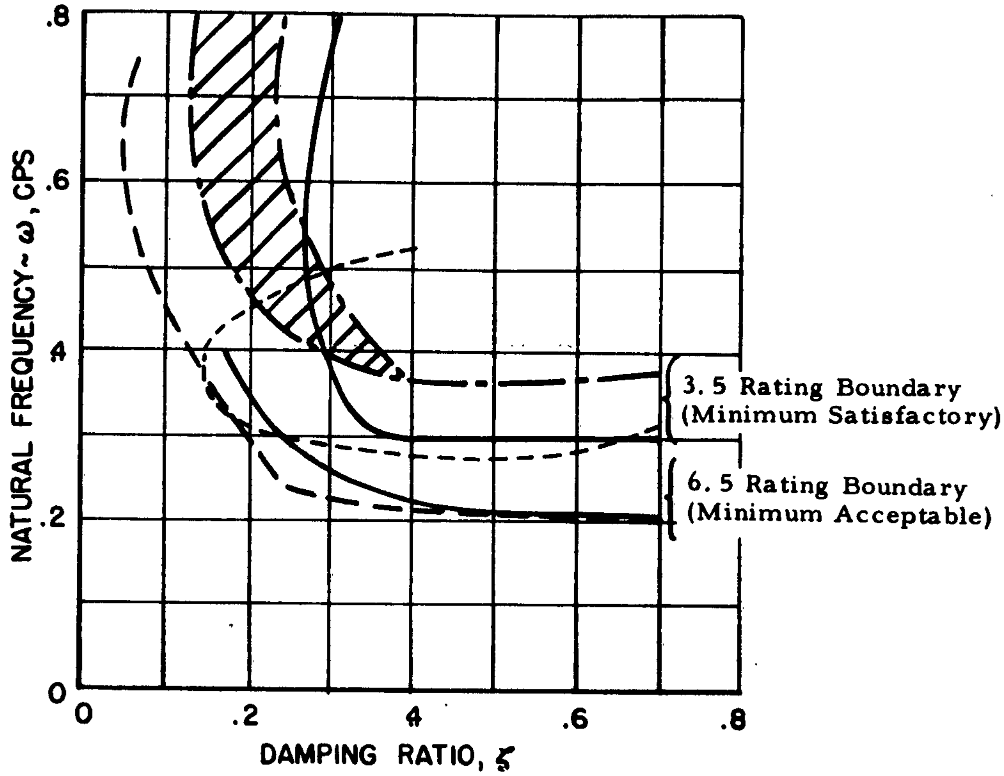


FIGURE 16 PILOT RATING BOUNDARIES



——— Long-Look - Pilots A, B, and C

-·—— F-94 Unsatisfactory Boundary (Reference 2)

– – – – T-33 Fixed-Base Minimum Acceptable Boundary (Reference 8)

--------- B-26 Poor Boundary (Reference 1)

Note: Significance of the boundaries obtained from the different tests is discussed on pages 20 and 21

FIGURE 17 RATING BOUNDARY COMPARISONS

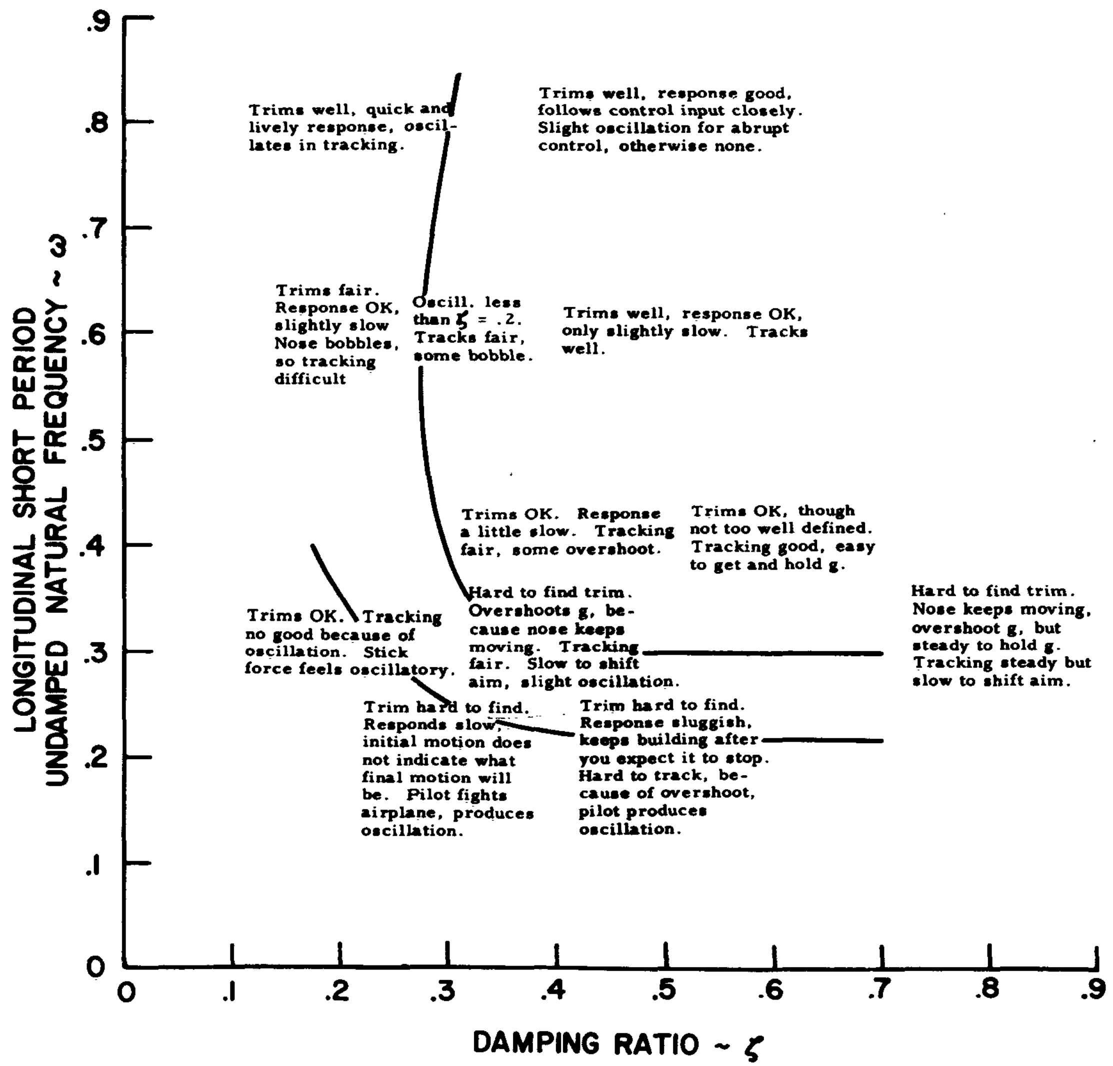


FIGURE 18 PILOT COMMENTS COMPARED TO RATING BOUNDARIES

APPENDIX A
BRIEFING FOR SHORT LOOK

1. Aim of Short-Look Evaluation.
2. Schedule:
   a. 16 configurations, plus as many more as convenient.
   b. Aim for about 4 minute evaluation, 1 minute of comment.
   c. Configurations occur in random order, therefore, a configuration is not necessarily a logical modification of the preceding one. It may be very different, or it may be very similar.
3. Maneuvers:
   a. Standard maneuvers developed on past program.
      (1) Trim straight and level
      (2) Rapid and slow entry and recovery in turns
      (3) Establish and maintain 0.5, 1.5, 2.0 g in push-over and pull-up
      (4) Acquire and track ground target in shallow dive
   b. Other maneuvers permissible if desired.
4. Comments and Ratings:
   a. Comment sheet supplied to help formulate your ideas.
   b. For short look, require only over-all rating, not rating on each maneuver. However, if one maneuver points out the major reason for the over-all rating, say so.
   c. Ratings should be given for the airplane as used tactically, rather than just as to whether it can be flown. For example, an airplane might be flyable but unusable. It would be rated Unacceptable, even though flyable. Ratings on both flyability and usability may be given, and are encouraged. An airplane might be rated 5 for flyability and 7 as a tactical airplane, for example.
   d. Do not hesitate to use the full range of the rating scale if it seems appropriate. On the other hand, you may get several configurations in a row which deserve the same rating. Don't look for imaginary differences between configurations; just call them as you see them.

4. Comments and Ratings (continued)

   e. Avoid comparison with the previous configuration in your comments. Make each commentary self-sufficient. For example, instead of "slower to respond than the last configuration, but OK", say "moderately quick response, which is OK", or whatever.

5. Comment Technique and Terminology:

   a. When ready to comment, say "Ready to comment". Crew man in the back will turn on wire recorder and say that he has turned it on. Then say "comments on configuration X", and go ahead.

   b. Use any convenient terminology. Scientific, engineering, pilot talk, or slang are all acceptable. Use whatever style helps you to get the idea across.

   c. Rather than attempt to define the motion of the airplane in mathematical terms, say what it did, how this affected your ability to use the airplane and what you thought of it. For example, "Airplane slow to start responding then tends to keep moving. Requires action from pilot to counteract this. Forces heavy to get started then lighten. OK to fly, stays on target when set but hard to acquire target or track moving target".

APPENDIX B
ANALYSIS OF VARIANCE - SHORT-LOOK DATA
(All Short-Look Configurations Less Number 27)

1. Pilots A - N

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots	110	13	8.46	4.49**
Configurations	485	14	34.6	18.4**
Error	343	182	1.88	

$\sigma_p = .662$ $\sigma_c = 1.53$ $\sigma = 1.37$

2. Pilots A - N, Less Pilots B, G, and H

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots	40	10	4.0	2.37*
Configurations	405	14	28.9	17.1**
Error	237	140	1.69	

$\sigma_p = .392$ $\sigma_c = 1.57$ $\sigma = 1.30$

3. Pilots A - N, Less Pilots B, F, G, and H

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots	25	9	2.78	1.42
Configurations	353	14	25.2	12.9**
Error	246	126	1.95	

(σ_p not significant) $\sigma_c = 1.53$ $\sigma = 1.40$

4. Pilots (A-C) Versus (D-N)

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots:				
(A-C) vs (D-N)	2.3	3	.77	.245
D-N	107.7	10	10.77	5.71**
Configurations	485	14	34.6	18.4**
Error	343	182	1.88	

* Significant at 5% probability level
** Significant at 1% probability level
σ_p = standard deviation due to pilots
σ_c = standard deviation due to configurations
σ = standard deviation due to experimental error

APPENDIX C

ANALYSIS OF VARIANCE - LONG-LOOK DATA

All Configurations (1 - 30)

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots	37	2	18.5	16.3*
Configurations	395	29	13.6	12.0**
Error	66	58	1.14	

$\sigma_p = .76$

$\sigma_c = 2.04$

$\sigma = 1.07$

All Short-Look Configurations (Less Configuration No. 27)†

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Pilots	17	2	8.5	5.1*
Configurations	182	14	13.0	7.81**
Error	46.7	28	1.67	

$\sigma_p = .675$

$\sigma_c = 1.95$

$\sigma = 1.29$

---

* Significant at 5% probability level

** Significant at 1% probability level

σ_p = Standard deviation due to pilots

σ_c = Standard deviation due to configurations

σ = Standard deviation due to experimental error.

† See page 15.

CONFIGURATION	PILOT A	PILOT B	PILOT C
1 $\omega = .8$ $\zeta = .2$	Little difficult to trim. Maintain trim once established with only slight residual oscillation if disturbed. Aircraft tracked well both in dive and level but pilot control motion induced a small oscillation which was damped. 6	Takes long to trim but remains in trim fairly good. Narrow trim band. Rapid response time. Tracking unsatisfactory. Considerable oscillatory motion. Tendency to overshoot. 7	Trim not too well defined. Aircraft has odd feeling due to rather quick response and high feel forces. Little over-responsive. Short period easy to excite. Short period oscillation not too noticeable in turn, more pronounced in tracking, during dive, and pull-out. 6
3 $\omega = .8$ $\zeta = .5$	Little more difficult to trim. Seemed to be high frequency oscillation superimposed on trim. Aircraft quickly damped after very high frequency oscillation. Tracking fairly easy except very high frequency superimposed on track. 4	Trimmability fair. Hold trim fair. Quick response. Poorly damped. Apparent lightening of F_s and therefore a tendency to overshoot. Tracking poor because of oscillatory motion. 7	Trimmability fair. Response to control almost too much, more than you need. Short period almost deadbeat. Almost overshot g because of quick response. Feels quite lively, little jerky. Notice a little bobble here and there. On dives, you almost get a PIO if you try to make continuous corrections. 5
5 $\omega = .6$ $\zeta = .2$	Easy to trim and remained in trim. Oscillation well damped in 1 cycle. Difficult to establish nose on horizon during entry into turns, but once established, fairly easy to maintain. Difficult to hold on target in dive, tends to overshoot. 5	Trimmability fair. Takes longer to trim, wider trim band. Oscillatory motion easily precipitated by trimming. Quick response from controls. Tendency to overcontrol. Tendency to bobble in tracking, apparent lightening of F_s. 7	No trouble to trim. Tends to remain in trim. F_s too high for fighter. Aircraft little tender in feel because of tendency to overshoot. Response quite lively and fighter type. You would probably overshoot trying to hold certain g. No problem tracking horizon. Track in dive not too satisfactory because of high F_s. 6
6 $\omega = .6$ $\zeta = .3$	Easy to trim. Oscillations damped in less than 1 cycle. Tendency for aircraft to wander while tracking. 4	Trimmability good. Hold trim good. Rapid response and not much conscious damping on the part of the pilot required for tracking. Tracking good. 4	Trimmability satisfactory. Feel rather good as far as getting response I want. Tracking is excellent primarily because of aircraft response. You can put it just where you want it. 2
7 $\omega = .6$ $\zeta = .5$	Easy to trim. Maintained trim within several knots. Oscillation essentially deadbeat. Very easy to track and hold on target. 1	Trimmability good. Hold trim good. Had impression of lightening of longitudinal control or aft c.g. Tracking satisfactory. 4	Trimmability pretty good. F_s nice and light. Aircraft response good. Feel good No noticeable stick motion. Holding g and tracking good. Aircraft quite responsive. Can make an exact maneuver with it very easily. 1
9 $\omega = .5$ $\zeta = .2$	Easy to trim and remained in trim. During control steps, oscillated 2 or 3 cycles before completely damped. Nose tended to oscillate while tracking. 5	Trimmability fair. Hold trim poor. Slow oscillatory motion ±7 or 8 knots. F_s seems high. Tendency to overcontrol because of high F_s. Tracking OK once on target. Bobbed getting on and recovering from tracking. 7	Trimmability adequate. F_s heavy - feels like a truck. Response all right, but rather soon. Holding g and tracking satisfactory but F_s/g too high. 5
12 $\omega = .5$ $\zeta = .4$	Fairly easy to trim and maintained trim well. Essentially deadbeat. Tracking was easy but detected very slow oscillation which required small attention from pilot. 2	Trimmability good. Holding trim good. Tracking satisfactory but tendency for nose to wander and cause overcontrolling. 4	Trimmability fairly good. Aircraft response-very adequate. F_s heavy. Turns and tracking very good. Tracking in dive OK except for high F_s required as speed increases. F_s too high for fighter, OK for transport. 2
14 $\omega = .4$ $\zeta = .1$	Exceptionally easy to trim and maintained trim with no oscillatory motion. Control steps induced very poorly damped oscillation. Very, very difficult to track because of poor damping. 7	Trimmability poor. Hold trim poor. Weakly damped. Pilot must work on damping himself. Apparent increase in F_s due to poor damping. Tracking poor. Overcontrolled on pull-out. Have to work on it all the time. 8	Trimmed OK. F_s satisfactory. Aircraft feel not good because of tenderness due to easily excitable short period. Holding g and tracking affected by poorly damped short period oscillations. 5

APPENDIX D PILOT C

SHORT-LOOK CO

12

	PILOT C		PILOT D		PILOT E		PILOT F	
7	Trim not too well defined. Aircraft has odd feeling due to rather quick response and high feel forces. Little over-responsive. Short period easy to excite. Short period oscillation not too noticeable in turn, more pronounced in tracking, during dive, and pull-out.	6	Trimmability hampered because aircraft bobs like cork. Damping good but period too short. F_s satisfactory. Control response good except for bobbing. Holding g, rapid turn entry and tracking all affected by bobbing.	7	Trimmability hampered because of over-sensitivity of aircraft. Very fast response to small inputs. F_s initially too light, but satisfactory once in maneuver. Response initially over-sensitive. Holding g, tracking, pull-ups difficult due to over-sensitivity. Flyable; but unacceptable for service.	7	Fairly easy to trim and stayed on fairly well. Fairly quick response. Difficult to maintain desired g without slight overshoot or hunting. Entry and recovery to turns affected by high frequency oscillation. Tracking on target was affected. F_s moderately heavy, unsatisfactory for fighter.	5
7	Trimmability fair. Response to control almost too much, more than you need. Short period almost deadbeat. Almost overshoot g because of quick response. Feels quite lively, little jerky. Notice a little bobble here and there. On dives, you almost get a PIO if you try to make continuous corrections.	5	Trimmability good. F_s heavy but good for this type. Control response good. Holding g easy in a slow entry. Fast entry causes a slight bobble. If motion is slow, damping is deadbeat. Ability to acquire and track target is function of entry rate.	4	Trimmability very poor. Appears to have almost neutral static stability. No F_s/V. F_s satisfactory. Response to control adequate and satisfactory. Holding g and tracking satisfactory. General feel of aircraft good but impaired by poor trimmability.	3	Difficult to trim. No oscillation in short period. Aircraft was very stiff. All maneuvers OK. Response to control average. F_s fairly good. Disliked the stiff longitudinal feel and not being able to precisely trim the aircraft.	5
7	No trouble to trim. Tends to remain in trim. F_s too high for fighter. Aircraft little tender in feel because of tendency to overshoot. Response quite lively and fighter type. You would probably overshoot trying to hold certain g. No problem tracking horizon. Track in dive not too satisfactory because of high F_s.	6	Trimmability good. F_s good for this type of aircraft, too heavy for fighter. Control response good. Damping not quite as much as I'd like, but it's liveable, not dangerous or bothersome. Hold desired g good. Very little tendency to oscillate while tracking. Little more than I would consider ideal, but suitable.	4	Slight stick motion to center trim in middle of friction band causes undesirable oscillations. F_s initially light but builds up to acceptable level. Apparent response of aircraft is fast initially, then becomes much slower. Apparent F_s lightening because of increased initial response. All tracking impaired by poor damping. General feel - very light and touchy.	6	Trimmed and maintained airspeed all right. Lightly damped oscillation but aircraft was fairly stiff. F_s moderate, satisfactory for heavier aircraft. Response to control fairly fast. Satisfactory to reach and hold desired g. Difficult to maintain precise altitude in level turn. Tracking fair.	4
4	Trimmability satisfactory. Feel rather good as far as getting response I want. Tracking is excellent primarily because of aircraft response. You can put it just where you want it.	2	Trimmability good. F_s quite light. Control response good. Holding g good. Slight oscillation both in trimming rapidly and tracking target. Personally like the response, but prefer little less bobbing.	2	Trimmability good. F_s satisfactory. Response to control seems little over-sensitive. Difficult to change attitude of aircraft minutely. Difficult in tracking. Aircraft just a little bit over-sensitive.	4	Easy to trim and stayed on trim. F_s OK for transport, heavy for fighter. Response satisfactory. Motion slightly oscillatory when tracking. Holding g, tracking ability, average.	3
4	Trimmability pretty good. F_s nice and light. Aircraft response good. Feel good No noticeable stick motion. Holding g and tracking good. Aircraft quite responsive. Can make an exact maneuver with it very easily.	1	Trims fairly well. Control response good. F_s fairly high for fighter, OK for bomber. Essentially deadbeat damping. Period is quite short but aircraft is readily handled. Aircraft feels a bit stiff, but not objectionable.	3	Aircraft response rather rapid, and there is seeming reduction in F_s. You have tendency to overshoot g you want. Track in turn and dive good. Push-over and pull-up response good initially but tend to overshoot. General feel of aircraft good.	4	Little difficult to trim and maintain. F_s OK for transport, too high for fighter. Response to control good. Maintain desired g good. All maneuvers good.	3.5
7	Trimmability adequate. F_s heavy - feels like a truck. Response all right, but rather soon. Holding g and tracking satisfactory but F_s/g too high.	5	Easy to fly straight and level or in steady turn unless disturbed, then an apparent undamped oscillation is caused. Actually very weak damping not apparent to pilot. Weakly damped oscillation causes very light F_s. Very difficult to hold certain g because of oscillation.	8	Trimmability satisfactory. Comments on all maneuvers satisfactory. General feel of aircraft fairly good. Damping is somewhat light, but definitely acceptable.	2	Trimmability OK. F_s too high. Response to control fairly rapid. Oscillatory short period made it slightly difficult to acquire and track target. Fairly easy to maintain level turn and desired g. Pilot had to damp out small oscillations in turns.	5
4	Trimmability fairly good. Aircraft response-very adequate. F_s heavy. Turns and tracking very good. Tracking in dive OK except for high F_s required as speed increases. F_s too high for fighter, OK for transport.	2	Trimmability satisfactory. F_s OK for this type, too heavy for fighter. Control response good. Hold g good. Longitudinal motion not objectionable in trimming and turning. Aircraft static stability very weak, mushy. It comes back but takes long time. Tracking OK.	2	Trimmability satisfactory. F_s OK. Response good. Slight tendency for oscillation when holding g. Tracking very good. Feel of aircraft very good.	1	Fair to trim, stayed on fairly well. F_s moderate to heavy. Response satisfactory. Motion oscillatory, fairly easy to maintain desired g. Level turns OK. Acquire and track target OK, although slight oscillation had to be damped out by pilot.	4
8	Trimmed OK. F_s satisfactory. Aircraft feel not good because of tenderness due to easily excitable short period. Holding g and tracking affected by poorly damped short period oscillations.	5	Trimmability hampered by poor short period damping. F_s OK. Response to control very poor because of poor damping. Response is generally more than you want and then bounces back. Holding g OK if you approach it very slowly. Anything done rapidly produces lightly damped oscillation.	7	Trimmability OK. F_s satisfactory. Neutrally damped. Period short enough so it is on borderline for PIO. Holding g marginal. Tracking unsatisfactory once short period is excited. General feel of aircraft unacceptable.	8	Difficult to trim because of high frequency neutrally damped short period, although aircraft could be trimmed. F_s exceptionally high, response to control OK except the motion was too high a frequency and undamped. Had to be damped out by pilot, which could be done but was difficult. All maneuvers difficult because of undamped oscillation.	8

APPENDIX D PILOT COMMENT DATA

SHORT-LOOK COMMENTS

CONFIG-URATION	PILOT G	PILOT H	PILOT I
1 $\omega = .8$ $\zeta = .2$	Trimmability acceptable and satisfactory. F_s little heavy but satisfactory. Response little slow but acceptable and satisfactory. Reach and maintain desired g rather poor due to frequency of short period oscillation. Entry and recovery to turns unacceptable. Track in turn and dive poor due to oscillation. General feel - unacceptable. 8	F_s satisfactory for fighter. Responsiveness rated 6 due to slight overshoot in attempting to track different target. Tactical rating 6, utility rating 7 because of light F_s/g. 6	Trimmability not bad. Fairly rapid response, high stiffness. Damping not too good. Very sensitive to stick motion. Frequency is high enough so that damping out oscillation by hand becomes difficult to impossible. Reach and maintain g not too bad. Turn entry and recovery jerky. Tracking once in turn or dive not good but can be done. Aircraft felt better with g's on. General feel - over-sensitive. 6
3 $\omega = .8$ $\zeta = .5$	Trimmability acceptable, F_s acceptable. Response to controls good. Reach and hold g good. Entry and recovery to turns satisfactory. Tracking in turn and dive acceptable and satisfactory. Push-over and pull-up good. General feel very good. 2	Very stif in pitch, too much for fighter. Rate it 7 for tactical in acquiring new target or originating maneuver in pitch. Rate it 4 utility, little too responsive in elevator but because of stiffness and ease of trim acceptable but unsatisfactory. Trimmability pretty good. 7	Trimmability satisfactory and remains in trim. F_s/g and F_s/V satisfactory. Abrupt control steps give oscillatory motion. Steady state motion OK but making small changes causes oscillations. Reach and hold g satisfactory except when making small changes. Same comment for other maneuvers. 5
5 $\omega = .6$ $\zeta = .2$	Trimmability satisfactory. F_s satisfactory, just a bit heavy. Response to control satisfactory. Reach and hold g acceptable but unsatisfactory. Push-over and pull-up acceptable. General feel acceptable but slightly unsatisfactory. 4	Tactical rating 7 because of high F_s required to maneuver and overshoot in acquiring or changing target. As utility, rating 4. F_s/g OK for utility, but oscillatory motion due to input undesirable for long haul. Too rapid response for transport causing passenger discomfort. 7	Trimmability satisfactory. Little slow but it doesn't appear to wander from trim. F_s OK. Response fairly rapid and comfortable in initial and final parts of motion. Maneuvers not good because very light damping causes oscillation. Frequency little too fast to damp out with stick. Not comfortable for tactical airplane. 6
6 $\omega = .6$ $\zeta = .3$	Trimmability satisfactory, but not particularly good. F_s high during initial part of motion, satisfactory during steady part. Response to control slow, unsatisfactory. Reach and hold desired g unacceptable due to high F_s and slight oscillation. Track in turn and dives acceptable, push-overs and pull-ups unacceptable because of F_s. General feel unacceptable. [illegible]	Difficult to trim. Bobbing effect of the nose. F_s too high for fighter. Control responsiveness good. For utility airplane, nose bobbing objectionable. F_s about acceptable and response can be lived with. 5	Trimmability satisfactory. Fairly high frequency rapid response to control. F_s OK. Reach and hold g quite easy and satisfactory. Tracking in turns a dives quite simple. Would like little better damping with this frequency. Push-over and pull-up fine - can set up and hold g. 3
7 $\omega = .6$ $\zeta = .5$	Trimmability satisfactory. F_s little high but acceptable. Response acceptable. Reach and hold g acceptable. Entry and recovery turns acceptable. Tracking in turns and dives acceptable but slightly objectionable because of F_s. General feel acceptable and satisfactory. 3	Good tracking and control response for fighter, but F_s/g too high for fighter. Good damping and about optimum F_s/g for utility. Responsiveness probably too high for utility. 3	Trimmability satisfactory. Damping satisfactory. Fairly high frequency. F_s/g quite high. Response quite rapid. Reach and hold g satisfactory. Little hard to get stabilized. Tracking in turn and dive little difficult but satisfactory. General feel - don't like it but don't know why. Acceptable but fair. 4
9 $\omega = .5$ $\zeta = .2$	Trimmability satisfactory. F_s little heavy but satisfactory. Response satisfactory, except final response resulted in overshoot of oscillatory nature. Reach and hold g fair but unacceptable. Track in dive acceptable but unsatisfactory. Push-over and pull-up acceptable but unsatisfactory. General feel unacceptable because of oscillatory motion. 7	Damping is poor and affects trim ability. Bad on long flights. F_s/g is on light side for utility. As tactical, responsiveness and F_s/g satisfactory, but poor damping gives tendency to overshoot on target acquisition. 3	Trimmability satisfactory. Fairly respectable frequency and quite poor damping. No tendency to overcontrol or force it. Response to control satisfactory. You can end up and hold a steady g once you learn to let it damp out and not fight it. Use this same technique in other maneuvers. Unsatisfactory for tactical. 5
12 $\omega = .5$ $\zeta = .4$	Trimmability acceptable and satisfactory. F_s little high, acceptable but unsatisfactory. Response acceptable and satisfactory, although short period oscillation noticeable but not real objectionable. Reach and hold g, entry and recovery turns acceptable and satisfactory. Tracking in turn and dive acceptable but unsatisfactory because of oscillation. Push-over and pull-up satisfactory. General feel acceptable but unsatisfactory. 4	Tactical rating 5 due to high F_s required to maneuver and slowness with which oscillations damp out. Utility rating 4 mainly because of rapid response to elevator. 5	Trimmability marginal. Takes considerable time to trim. F_s/V quite light and controllable. F_s OK. Damping is too low. [illegible] cycle to damp out. Maneuvers can be done although not good because of oscillation. Frequency is such that you can't over control it. Acceptable but only fair aircraft 4
14 $\omega = .4$ $\zeta = .1$	Trimmability satisfactory. F_s OK. Response OK except for oscillatory motion. Reach and hold g very poor because of oscillation. Entry and recovery to turns very poor. Tracking in turn and dive very poor. Push-over and pull-up response OK except can't really control it due to oscillation. General feel very poor. 9	Unacceptable and dangerous for either category because of poorly damped pitching. Unacceptable as transport because of ease of overstressing. It's not unflyable, I'd get it back home. 9	Trimmability and F_s satisfactory. Cannot hold desired g although not difficult to reach. Low damping not enough to stabilize on g. Frequency is slow enough that you can damp aircraft yourself in turn entry and recovery. Push-over and pull-up response unsatisfactory because you can't fly g schedule. Cannot damp it out from feel 6

SHORT-LOOK COMMENT

2

PILOT I	PILOT J	PILOT K	PILOT L
...ability not bad. Fairly rapid response, ...ffness. Damping not too good. Very ...e to stick motion. Frequency is high so that damping out oscillation by hand is difficult to impossible. Reach and ...g g not too bad. Turn entry and recov...y. Tracking once in turn or dive not ...t can be done. Aircraft felt better with ... General feel - over-sensitive. **6**	Trimmability satisfactory. Gives impression of very light stick forces for initial deflection, very rapid response for light forces and then forces become heavier as g's are applied. Holding g satisfactory for 1.2 and 2 g. For small g deflection, not easy to stay on g schedule. Tracking in turns satisfactory; in dives, fair due to light F_s required for small deflections of aircraft. **4**	Very difficult to trim. Aircraft felt pretty good when making slow smooth gentle maneuvers. Got oscillation when using rapid control movement. Pilot could take care of oscillation, though. **5**	Excessive springy damping. Initial aircraft responce too great for relatively small F_s applied, particularly noticeable in push-over, pull-up and initiation of any maneuver. General feel - very stiff statically but too springy dynamically. **6**
...ability satisfactory and remains in ...F_s/g and F_s/V satisfactory. Abrupt ...steps give osciliatory motion. Steady ...tion OK but making small changes ...oscillations. Reach and hold g sat...y except when making small changes. ...mment for other maneuvers. **5**	Trimmability poor. Trim speed seems wide. F_s light. Aircraft seems rather jumpy as an immediate response to light control forces. Tendency to overcontrol while tracking in turns, same in dives. Airspeed does not seem to cause much change in F_s in dive. Aircraft too jumpy, too rapid in response. **5**	Trims well. When applying control, aircraft seems to hesitate before starting to move, then moves rapidly. Tracking ground target extremely difficult. Tends to oscillate about point. Continually trying to correct. **9**	Trimmability excellent. All aspects excellent. Excellent static longitudinal F_s stability and good damping that's deadbeat but not imposed in such a fast rate that it is objectionable. **2**
...ability satisfactory. Little slow but it ...appear to wander from trim. F_s OK. ...se fairly rapid and comfortable in ...ma final parts of motion. Maneuvers ...l because very light damping causes ...tion. Frequency little too fast to damp ...stick. Not comfortable for tactical ...e. **6**	F_s seem light at first and increase as g is applied. Quick response. Fairly easy to hold g schedule. Tracking in turns satisfactory. Got small oscillations of nose above and below target when tracking in dive. Rather hard to control. Harder to track in dive than to hold g. General feeling good except for tracking in dive. **4**	Aircraft appeared sensitive. Tend to overshoot target, but you can bring it back on target. Oscillation tends to cause you to overshoot and undershoot. **6**	General opinion of aircraft excellent. Only adverse comment - short period requires 1.25 to 2.25 cycles to damp depending on F_s input. No adverse comments on various maneuvers. I like this type of damping personally and rather have it than deadbeat. Excellent rating. **2**
...ability satiafactory. Fairly high fre... ...rapid response to control. F_s OK. ...and hold g quite easy and satisfactory. ...ng in turns a dives quite simple. ...like little better damping with this ...cy. Push-over and pull-up fine, can ...and hold g. **3**	F_s seem little higher than I like them. Not much else wrong with configuration. Track OK. Holding g satisfactory. Aircraft does seem little sluggish and I feel this may be due to higher F_s than I like. Tracking in dive good. **4**	Easy to trim. Easy to handle. Had slight oscillation when getting on target, appears more or less pilot induced. **2.5**	Trim easy to hold. Highly damped. Initial F_s is lighter than final F_s during transient. This gives springy, spongy aircraft response to initial light F_s. F_s and aircraft response satisfactory. Reach and hold g excellent. Turn entry and recovery very good. Tracking in dive, push-over and pull-up good. General feel very good with possibility of sponginess or springiness due to apparent overdamping. **3**
...ability satisfactory. Damping satis... Fairly high frequency. F_s/g quite ... Response quite rapid. Reach and hold ...factory. Little hard to get stabilized. ...ng in turn and dive little difficult but ...tory. General feel - don't like it but ...now why. Acceptable but fair. **4**	Easy to trim. Seems to have neutral static stability, i.e., holds several different airspeeds. Damps out fast. Very rapid response. Maintain g good. Slight tendency to overshoot on first attempt. Turn entry and recovery, tracking good. F_s seem light. Acts like a fighter, like it very well. **2**	Easy to trim. Aircraft goes to where you put it, but seems just a little sensitive. F_s little higher than I like. **3**	Excellent characteristics. Lighter F_s. All aspects excellent. **2**
...ability satisfactory. Fairly respec... ...requency and quite poor damping. No ...y to overcontrol or force it. Response ...rol satisfactory. You can end up and ...steady g once you learn to let it damp ...l not fight it. Use this same technique ...r maneuvers. Unsatisfactory for ...i. **5**	Trimmability satisfactory. Short period seems little shorter than I like. Responds quickly and well. g schedule fairly easy when constant forces are applied. Tracking in turn good when positive force applied, little nose oscillation when force is released. Tracking in dive satisfactory. **3**	Easy to trim. Nice F_s. Handled real nice, felt good. Could get on target quicly and hold target very well. **2**	Trimmability acceptable but not good. Aircraft gives impression of having neutral to negative static stability with poor damping superimposed. Damping is sluggish and excessive number of cycles such that response is unnatural to F_s initially applied. Tracking, push-over and pull-up all OK. Excessive aircraft response to F_s initially. **6**
...ability marginal. Takes considerable ...trim. F_s/V quite light and comfort... F_s OK. Damping is too low, 1.25 ...to damp out. Maneuvers can be done, ...n not good because of oscillation. ...ncy is such that you can't over...d it. Acceptable but only fair aircraft. **4**	Rather difficult to trim and hold. Aircraft responds fairly well. F_s seem little high. While holding g greater than 1, F_s seem to vary while holding constant g. Tracking in turns satisfactory. Easier to track in turns than hold g schedule. **4**	Aircraft handles very nicely, responds well. Light F_s. Can't pin it down but I can't hold it on target quite as well as I'd like to. **2**	All aspects excellent. **1**
...ability and F_s satisfactory. Cannot ...desired g although not difficult to reach. ...amping not enough to stabilize on g. ...ency is slow enough that you can damp ...alt yourself in turn entry and recovery. ...over and pull-up response unsatisfac...because you can't fly g schedule. Cannot ...it out from feel. **6**	Trimmability poor. Hard to trim out precisely. F_s acceptable. All maneuvers difficult due to oscillation. Appears that under some conditions aircraft might become dangerous and diverge if too rapid and too strong F_s applied. **7**	Very difficult to trim. Never seems to be quite in trim due to oscillation. F_s excessive and make maneuvering extremely difficult. Could not hold a certain g due to oscillations. Frequency was slow enough pilot could react to them, but kept him busy. Could not settle on g or target in tracking. **8**	Poorly damped oscillation makes forces too light for aircraft response. Aircraft response initially too fast, relatively mild F_s inputs. Could reach and hold g, also track in turn and dive but both became more difficult farther away from trim. Mild to moderate damping required from pilot. General feel - would be greatly improved with improved damping. **7**

SHORT-LOOK COMMENTS (CONTINUED)

CONFIG-URATION	PILOT M	PILOT N	PILOT O
1 ω = .8 ζ = .2	Trimmability good. F_s satisfactory. Airfract response little too touchy - something like Configuration 3 but period seems little longer and damping doesn't seem as good. Entry and recovery from turns OK. Kind of a step input when I get to 1.5 g. Aircraft very sensitive. Poor damping seems to make it appear easier to control. Frequency appears little bit high. 2	Difficult to trim. F_s good. Short period fairly rapid oscillation going on all the time. This was true in all maneuvers. Just a little bobble no matter what I did to try to correct it. This bobble makes configuration very poor. 7	Trimmability fair. ±5 knot. High frequency and low damping makes airplane "touchy, goosey". In tracking, you run into bobbling and bouncing around of the nose when attempting to change nose position. 6
3 ω = .8 ζ = .5	Trimmability good. Response good. Reach and hold g good. Aircraft is excellent but response is too good for aircraft like this. 1.5	Fairly easy to trim. F_s just little heavier than I like. Holding g, entry and recovery from turns pretty easy. Tracking in turns and dives rather poor because of small longitudinal motions for very small stick motion, and I couldn't actually put nose right on target. General feel - good except for this rather quick response for very small stick motion. 4	
5 ω = .6 ζ = .2	Trimmability marginally satisfactory. Static stability relatively neutral. F_s OK. Aircraft response very good except frequency is too high. Reach and hold g and entry and recovery from turns OK. Tracking in turns and dives - frequency little bit too high for good fine control. 3	Fairly easy to trim. Quick response for initial light F_s. F_s too high once in steady turn or g. Initial response sets up little oscillation but damps out real quickly and not too objectionable with a little practice. Maneuvers are fair as long as you don't make abrupt motions. General feel good to fair. 3.5	
6 ω = .6 ζ = .3	Trimmability satisfactory. Took little longer. Static stability essentially neutral. F_s appears little higher than desirable. Response pretty sluggish, probably masked by idea of too high F_s/g. Maneuvers fair. Push-over and pull-up - doesn't damp quite as good as it should. 4	Quite easy to trim. F_s OK. Reach and hold g OK. (Seems to be lag in stick position. Have to keep moving stick aft to maintain same force. Little difficulty in tracking ground target because of oscillation. Moving from target to target was smooth but got bobble when stopped on target. 3	
7 ω = .6 ζ = .5	Appears pretty nice. Trimmability OK. All maneuvers OK. 2	All aspects considered good to excellent. Would prefer just slightly lighter F_s. General feel excellent, the way a flying machine should fly. 1.5	Trimmability fair. Same comments as Configuration 9. Tracking in turns good. Tracking in dive pretty good except for very small oscillation at end when making nose correction. 3
9 ω = .5 ζ = .2	Trimmability satisfactory. Damping should be higher. Abrupt control inputs up to 2 g and down to .4 indicate slightly higher frequency than is desirable. Frequency is too high in dives to do anything about tracking successfully. 4	Slightly difficult to trim. Holds pretty well. Initial response excessive for very light F_s and in steady turn F_s is too high. Short period oscillation easily excited and undesirable. Reach and hold g satisfactory. Track in turns and dives fair as long as you don't excite short period; no quick movements; 4 to 5 cycles to damp. Seemed better to just let it damp out by itself. General feeling poor to fair - quick response. 4	Trimmability 2. Took while to get it trimmed, but then pretty well locked on. Tracking and changing nose position good. Didn't have much success in damping short period without running into a lot of very small oscillations after major damping had been cleared out. 4
12 ω = .5 ζ = .4	Trimmability good. F_s satisfactory. Aircraft response good. All maneuvers good. No undamped or residual oscillation. 2	Very easy to trim. F_s little heavy at first but under higher g's its' good. Reach and hold g excellent. Track in turn and dive fair. Push-over and pull-up good. Tended to overcontrol in tracking because I liked relatively lighter breakout forces. General feel excellent. 2.5	Trimmability fair. Residual drift in trim of about 5 knots. Tracking in turns, dives good. No trouble holding g, able to get nose around and hold it where wanted. Damping was most pronounced in first half of oscillation, was confused by damping in last quarter of cycle. 4
14 ω = .4 ζ = .1	Aircraft has fairly undamped oscillatory mode. Static stability satisfactory. Ability to reach and hold desired g is there, but that's all I can say for it. Track in turn and dive OK as long as there's a control force applied. Any reduction in F_s results in relatively undamped oscillation. 7	Difficult to trim. F_s little heavy throughout initial part of motion and after once in turn or established on g. Ability to do maneuvers is fair once established but abrupt control excites oscillation. General feel very poor. Can fly aircraft safely but difficult to do any mission requiring maneuvering. Reaction is I just wouldn't want to fly it. 7	

SHORT-LOOK COMMENTS (CONTINUED)

CONFIGURATION	PILOT A	PILOT B	PILOT C
15 $\omega = .4$ $\zeta = .2$	Easy to trim and hold trim. Oscillation positively damped but slowly. Fairly easy to track but slow oscillation (long period) superimposed on top of tracking envelope. Not as noticeable in dive. 4	Trimmability good. Hold trim good. Oscillatory motion, objectionable. You have to work at getting it out yourself. Tracking, tendency to overcontrol. 5	Trims up nicely. Light F_s. Aircraft response good. Short period is quite short and lightly damped, but does damp out. This doesn't bother you in tracking. 2
16 $\omega = .4$ $\zeta = .3$	Exceptionally easy to trim and held trim very well. During steps, initial return was fairly rapid. Tracked very well level and pretty good in dive. Aircraft seemed to wander a little in dive and required some heavy F_s. 2	Trimmability good. Small tendency for aircraft to go off trim. Tracking good. 4	Trimmability satisfactory. F_s OK for transport. Aircraft response good. Holding g and tracking satisfactory although F_s higher than desirable in dive. I can't really find anything I dislike but I'm not perfectly happy. 3
19 $\omega = .4$ $\zeta = .5$	Trimmed and held trim well. Almost deadbeat. Aircraft tracked very well in level turns but stick forces had to be increased a fair amount in dive. 2	Trimmability good. Hold trim good. Tracking good. 3	Trimmability not absolutely perfect but as good as could be asked for. F_s just about as I'd like to see in an average airplane. Aircraft response and feel very good. Delightful to fly. Tracking good. No noticeable stick motion. Overall as nice as I've ever flown. 1
22 $\omega = .3$ $\zeta = .2$	Not too easy to trim. Once trimmed, held well. On control steps, aircraft made one initial overcorrection and then slowly damped. Slow oscillation present in all tracking. 6	Almost neutrally stable trim band ±10 - 15 knots. Apparent increase in F_s. Response time slow. Quite a bit of oscillatory motion once aircraft moves and slow to damp out. Tracking poor because of this. 7.5	No trouble in trimming. Aircraft response to control weak. Time lag in response objectionable. Short period very weakly damped. Not comfortable at large g input. Difficult to damp manually because pilot finds it difficult keeping up. Holding g and tracking not good because of oscillatory short period. 7
23 $\omega = .3$ $\zeta = .4$	Little bit difficult to trim. Began to drift off after short time. Very well damped. Took some effort to keep nose on horizon around 180° turn. Tracking in dive good. 3	Trimmability good. Hold trim good. Tracking - once aircraft gets moving there is a tendency to overshoot. Increase in F_s during tracking, more difficult to track. Oscillatory motion difficult to damp. 5	Trimmability adequate. F_s moderately light. Aircraft response somewhat sluggish. Tracking OK except again response is on sluggish side. 3
26 $\omega = .3$ $\zeta = .8$	Easy to trim. Remained in trim fairly well. Airplane did not oscillate, just assumed new attitude when stick was released. Tracked well. 2	Trimmability - wide trim band. Hold trim good. F_s seemingly heavy. Slow response, heavily damped. Tracking poor because of slow response; tendency to overcontrol. Difficult to get aircraft to move. Once on target easy to hold there. 6	Seemingly difficult to trim up but not really. Fairly neutral static force stability. Nice for maneuvering aircraft. Short period well damped. Tracking easy. Response decent. F_s decently light. Rated 2 rather than 1 because would prefer lighter stick force. 2
27 $\omega = .2$ $\zeta = .3$	Unable to do - system troubles.	Trimmability poor. Continually hunting, little ability to remain in trim. Constant oscillatory motion. Response lag to control input, consequently tendency to overshoot. 7	Not too hard to trim. Hard to define. High F_s. Aircraft response low for what you want. Divergent short period excites pilot and he tends to overcontrol. Pilot almost out of phase with it. Not quite a PIO but approaching it. Period is long enough so you do have control over it. 7
28 $\omega = .2$ $\zeta = .5$	More difficult to trim than usual. When disturbed it assumed new speed with no tendency to return to original trim. Tracked well unless disturbed, then would assume new trim. 7	Very little feel as far as trim. Aircraft response time to control somewhat delayed, resulting in tendency to overcontrol. Tendency to overcontrol in tracking. 7	Ability to trim not bad but no tendency to come back once displaced. Abrupt roll steps result in PIO. Similar to F8U at high q but not uncontrollable. Disconcerting. Slow response becomes objectionable during entry into turns. Doesn't go where you want it with stick you put in. Putting in more and overshooting little each time. 7

SHORT-LOOK COMMENTS

12

	PILOT C	PILOT D	PILOT E	PILOT F
5	Trims up nicely. Light F_s. Aircraft response good. Short period is quite short and lightly damped, but does damp out. This doesn't bother you in tracking. 2	Trimmability hampered by inadequate short period damping. F_s OK for this type. Response to control good. Holding g also hampered by poor damping. Longitudinal motion is stable but requires more damping for good handling characteristics. Ability to acquire and track target marginal. 5	Trimmability poor. Same comments as Configuration 5. Once trimmed it holds. Increase in F_s in oscillatory motion. F_s initially satisfactory however. Aircraft response initially satisfactory. Tracking unsatisfactory because of poor damping. General feel good but sloppiness due to inability to put nose where you want it. 5	Fairly easy to trim and hold trim OK. F_s high. Response to control fairly fast, but oscillation occurred when changing target in tracking and maintaining g. Frequency was in range where pilot could damp it out fairly fast. Once on target, tracking was fairly steady. 7
4	Trimmability satisfactory. F_s OK for transport. Aircraft response good. Holding g and tracking satisfactory although F_s higher than desirable in dive. I can't really find anything I dislike but I'm not perfectly happy. 3	Poor damping. Tracking in turn OK. Tracking in dive and holding g difficult because of oscillations. Response when making quick entry into maneuvers was more than I wanted, and produced oscillations. Slow entry gave more or less desired response. 4	Trimmability satisfactory. F_s initially OK, a little high during steady turns. All maneuvers satisfactory. No tendency to overshoot. Excellent aircraft. 1	Fairly easy to trim. F_s OK. Response quick but underdamped and therefore oscillation on short period. Difficult to maintain level turns. Tracking difficult. 5
3	Trimmability not absolutely perfect but as good as could be asked for. F_s just about as I'd like to see in an average airplane. Aircraft response and feel very good. Delightful to fly. Tracking good. No noticeable stick motion. Overall as nice as I've ever flown. 1	Trimming fairly easy. F_s high but acceptable for this type, too high for fighter. Control response good both in time and motion. Holding g good. Short period well damped. At first, appears aircraft is statically unstable but turns out phugoid period is 60-70 seconds which is annoying in straight and level. Tracking good. 3	Trimmability good. F_s seems to decrease as g built up. Aircraft response to control initially good. Slight oscillation in turns makes tracking difficult. Oscillations while holding g. Oscillations most pronounced in turns. General feel of aircraft good. 4	Slightly difficult to trim. Average in remaining in trim. No oscillatory motion in trimming. Slight overshoot when putting in control steps. F_s slightly high, too high for fighter. Response to control satisfactory. Easy to reach and maintain g and level turns. Tracking satisfactory. Slight overshoot in acquiring target could be easily damped. 3
7.5	No trouble in trimming. Aircraft response to control weak. Time lag in response objectionable. Short period very weakly damped. Not comfortable at large g input. Difficult to damp manually because pilot finds it difficult keeping up. Holding g and tracking not good because of oscillatory short period. 7	Aircraft is very sensitive and damping is too low. F_s are so light that aircraft could be overstressed by pilot. Tracking in dive and trying to hold g induce oscillations. Can handle it but don't like it. Could lead to structural failure in combat. 6	Trimmability satisfactory. F_s satisfactory. Aircraft response satisfactory. Neutrally damped short period can be damped manually. Holding g and tracking hampered by oscillations. Difficult to make small corrections. Aircraft is flyable but unacceptable for certain service use. 7	Aircraft was trimmable but difficult due to oscillations. F_s moderately heavy, satisfactory for fighter. Response to control was fast, motion oscillatory and lightly damped which could cause g overshoot. Ability to reach and maintain g almost impossible. Entry and recovery turns, holding g very erratic. Difficult to track target. 8.5
5	Trimmability adequate. F_s moderately light. Aircraft response somewhat sluggish. Tracking OK except again response is on sluggish side. 3	Trimmability good. F_s OK for this type. Too heavy for fighter. Control response good. Holding g good. Tracking good. Consider aircraft very easy to use in combat. 2	Trimmability difficult, bordering on neutral static stability. F_s satisfactory. Holding g satisfactory. Push-over and pull-up response satisfactory. Tracking hampered by light damping. Easy to damp out, however. In general, aircraft was fair. 4	Slightly difficult to trim. Once trimmed, stayed OK. F_s moderately heavy - OK for transport. Quick response to control. Motion lightly damped. Slight difficulty in tracking target and reaching and holding g. Fairly easy to maintain level turns. 4
8	Seemingly difficult to trim up but not really. Fairly neutral static force stability. Nice for maneuvering aircraft. Short period well damped. Tracking easy. Response decent. F_s decently light. Rated 2 rather than 1 because would prefer lighter stick force. 2	Not difficult to trim but annoying. F_s lighter than should be for this type. Control response good. Holding g marginal. Always got more than I want. Some stability but practically all masked by control force friction. Aircraft doesn't return to equilibrium when displaced. Tracking OK. 4	Trimmability poor. Very poor feel around trim. F_s satisfactory. Response of aircraft good. Just about deadbeat. Holding g, tracking satisfactory. General feel of aircraft good. Only drawback is inability to trim. 3	Difficult to trim. F_s good. Response to controls was fair, possibly good. Maintaining desired g unsatisfactory since F_s seemed to vary. You had to hunt to try to hold desired g. No oscillation. Fairly easy to hold level turn, difficult to hold constant g's in turn. Easy to acquire and track target. 6
7	Not too hard to trim. Hard to define. High F_s. Aircraft response low for what you want. Divergent short period excites pilot and he tends to overcontrol. Pilot almost out of phase with it. Not quite a PIO but approaching it. Period is long enough so you do have control over it. 7	Trimmability unsatisfactory. F_s too light for this aircraft. Control response immediate and too sensitive. Holding g unsatisfactory. Unusually long short period. Acquire and track target almost nonexistent. Overall very bad, possibly dangerous. 8	Trimmability impaired by oscillations caused by small control inputs. F_s initially OK. Aircraft response initially too slow, therefore you want to put in a forcing input to increase movement. Light damping, relatively long period leads to tendency for overcontrolling and PIO. General feel of aircraft bordering on dangerous. 9	Aircraft could be trimmed once feel had been obtained, stayed in trim fairly well. Low frequency oscillation, easy to get out of phase with. F_s moderate and response to control fairly fast. Light damped, low frequency oscillation easy to overshoot and get a PIO. Difficult to make level turn, acquire and track target. PIO tendency when trying to change targets too quick. 9
7	Ability to trim not bad but no tendency to come back once displaced. Abrupt roll steps result in PIO. Similar to F8U at high q but not uncontrollable. Disconcerting. Slow response becomes objectionable during entry into turns. Doesn't go where you want it with stick you put in. Putting in more and overshooting little each time. 7	Not very difficult to maintain trim, but any disturbance sets up oscillations. Apparent negative damping. PIO tendency because of this. Response always more than I want. Could be dangerous structurally. 8	Trimmability impaired by apparent neutral static stability. F_s initially light and remains so, therefore tendency to overshoot and requires heavy input in opposite direction. Desire to try to force aircraft to go faster than initially going then forcing function takes over and you get too great a response. Tracking unacceptable due to PIO. 8	Difficult to trim because of very low frequency oscillation. Held fairly well when trimmed. F_s moderate to OK for transport, heavy for fighter. Response slow, motion tended to overcontrol. Could actually damp it out. Turns, tracking difficult. 7

SHORT-LOOK COMMENTS (CONTINUED)

CONFIG-URATION	PILOT G	PILOT H	PILOT I
15 $\omega = .4$ $\zeta = .2$	Easy to trim and stayed fairly well in trim. F_s acceptable. Response to control overly sensitive, both initially and finally. Reach and hold g - marginal. Short period oscillation made all maneuvers unsatisfactory to unacceptable. Did not like general feel of airplane because I couldn't control it due to oscillatory motions. 8	Tactical rating 6 due to high F_s during turning maneuvers in tracking. Response satisfactory. Oscillatory motion resulting from pitch changes unsatisfactory for utility airplane. 6	Trimmability adversely affected by long phugoid. Frequency moderate and damping quite poor. Oscillation could be damped out manually. F_s/g seemed fairly high. Oscillations during maneuvers could be damped out by hand but high forces required some effort. Easier to fly VFR than IFR. More comfortable forcing nose into position than to allow aircraft to fly itself. 6
16 $\omega = .4$ $\zeta = .3$	Trimmability acceptable and satisfactory. F_s satisfactory. Response satisfactory except for short period oscillation. Reach and hold g acceptable but unsatisfactory. Entry and recovery turns acceptable but unsatisfactory. Track in turn and dives unacceptable. Push-over and pull-up unacceptable. General feel unacceptable. 7	Trimmability relatively difficult. F_s satisfactory for tactical. Tendency to overshoot because of relatively poor damping. Difficult not to overshoot acquiring new target. F_s little too light as utility. 5	Trimmability satisfactory. Moderate frequency, relatively poor damping. F_s/g rather heavy. Oscillation frequency is low enough you can damp out by hand. Turn entry and recovery little bit rough but not bad. Tracking in turn and dive satisfactory. Push-over and pull-up response OK. Would prefer more damping. 4
19 $\omega = .4$ $\zeta = .5$	Trimmability acceptable. F_s little heavy, not too objectionable. Response perhaps little slow but acceptable. Reach and hold g acceptable and good. Entry and recovery turns satisfactory. Track in turn and dive acceptable and very good. Push-over and pull-up satisfactory. General feel acceptable and satisfactory. 2	Tactical rating 7, slow response, high F_s required to maneuver and tendency to overshoot slightly in acquiring target. Utility rating 3. F_s/g about right for utility, response adequate and trimmability fair. 7	Light F_s/V gradient. F_s/g satisfactory. Little hard to trim. Response initially tended to overcontrol in going into turn because of light F_s gradient. Satisfactory once in turn. Reach and hold g satisfactory. Tracking satisfactory. Push-over and pull-up response quite light. 3
22 $\omega = .3$ $\zeta = .2$	Trimmability acceptable but unsatisfactory. F_s acceptable. Response acceptable but oscillation makes it difficult to fly airplane with any precision. Reach and hold g unacceptable. Entry and recovery turn unsatisfactory. Track in turn and dive unacceptable. Push-over and pull-up acceptable but unsatisfactory. General feel unacceptable. 8	Similar to Configuration 14, not quite as dangerous. Very bad oscillatory characteristics and poor damping. 6	Very lightly damped. F_s/g satisfactory. Frequency low enough to control nose position but uncomfortable to fly and unsatisfactory for tactical. Not easy to track. Reaching and holding g not comfortable because of oscillation. Push-over and pull-up satisfactory except for inability to stabilise on g. 6
23 $\omega = .3$ $\zeta = .4$	Some difficulty in trimming. F_s satisfactory. Response to control acceptable except for oscillatory nature of short period. Reach and maintain g not acceptable. Track in turn and dive acceptable but unsatisfactory. Push-over and pull-up response satisfactory. General feel of aircraft acceptable but unsatisfactory. 7	Trimmability affected by poor damping and oscillatory motion in gusty air. F_s/g unacceptably high and response poor for fighter. F_s/g satisfactory for utility but difficult to trim. 7	Trimmability satisfactory. F_s satisfactory. Frequency is quite low and damping relatively poor. No tendency to try to drive it or overcontrol it. Response shows oscillatory motion in trying to stabilise in turn. Frequency is low enough you can usually damp out oscillation. Could also do it on sensitive accelerometer when rapidly changing targets. You run into problems with low frequency. 5
26 $\omega = .3$ $\zeta = .8$	Trimmability poor. F_s not objectionable. Response satisfactory. Reach and maintain g acceptable and satisfactory. Entry and recovery turn satisfactory. Track in turn and dive fairly good and acceptable. Push-over and pull-up satisfactory. General feel acceptable and satisfactory. 3	Deadbeat. Tracking good. Changing target good. F_s light enough for tactical. Utility rating 5 because of rapid response to elevator and light F_s. F_s too heavy for fighter. Difficult to stabilize on target. 3	Trim difficult to get set up but remains on good. Response quite slow. Find yourself trying to hurry aircraft with change in F_s. End up having high F_s in entries, then reduction in F_s. Cannot hold fine tracking, other maneuvers not too bad. General feel fairly sluggish. Poor aircraft for tactical maneuvering. 5
27 $\omega = .2$ $\zeta = .3$	Trimmability poor and unacceptable. F_s satisfactory. Response to control initially OK but final response poorer because of reversal in F_s required to stop it at given attitude. Reach and hold g very poor and unacceptable due to overshoot. Other maneuvers very poor and unacceptable. Inability to precisely control aircraft. General feel very poor and unacceptable. 9	PIO tendency easily reinforced by poor pilot technique. 9	Short period quite slow and damping close to neutral. F_s quite high in initial part of motion, then motion becomes a continually oscillatory mode. Tendency to overcontrol, continually fighting aircraft. In maneuvers aircraft wants to diverge; you have to watch how much control you put in. Can't really track with aircraft. 8
28 $\omega = .2$ $\zeta = .5$	Trimmability very poor. Actually unable to trim. F_s acceptable. Response to control very poor because of tendency to overcontrol immediately following initial application of force. Reach and hold g unacceptable due to overshoot. Tracking in turn and dive unacceptable. Push-over and pull-up unacceptable due to weak damping and tendency to overcontrol. General feel unacceptable. 9	Tendency to pitch up or down on control deflection. F_s/g for fighter too high causing a tendency to muscle any pitch changes and this aggravates overshoot. Not damped enough for transport. 9	Very responsive to trim. Apparently high F_s commencing maneuver you realize are due to your forcing aircraft to do what you want to get. Response is very slow. Tendency to overcontrol in all maneuvers. Cannot stabilise in tracking. General feel unacceptable. 7

SHORT-LOOK COMMENT

2

	PILOT I	PILOT J	PILOT K	PILOT L
turning isfactory. h lane. 6	Trimmability adversely affected by long phugoid. Frequency moderate and damping quite poor. Oscillation could be damped out manually. F_s/g seemed fairly high. Oscillations during maneuvers could be damped out by hand but high forces required some effort. Easier to fly VFR than IFR. More comfortable forcing nose into position than to allow aircraft to fly itself. 6	Trimmability satisfactory and remains in trim. Hard to hold desired g because F_s seem to be changing and position of stick also noticeably changing with force. Tracking in turns and dives not difficult. g overshoot tendency does not seem to be present when applying negative g or holding in the dive. General feel - forces are moderate but airplane response little too rapid. 4	Trimming - no problems. F_s little high and aircraft tended to dig in whenever you applied positive g. Not so noticeable in nosing over. Tracking target fairly good. 6	Difficult to trim in turbulence. Don't like damping, it gives way too much oscillation, too difficult to damp out, too loose. Period is rather short. Attaining g may or may not be a problem. 7
satis- rshoot Difficult F_s 5	Trimmability satisfactory. Moderate frequency, relatively poor damping. F_s/g rather heavy. Oscillation frequency is low enough you can damp out by hand. Turn entry and recovery little bit rough but not bad. Tracking in turn and dive satisfactory. Push-over and pull-up response OK. Would prefer more damping. 4	Trimmability satisfactory. F_s moderate and satisfactory. Response good. Responds immediately to control. Holding g easy at .5 g; at 1.5 and 2.0 there's slight oscillation. Tracking in turn and dive satisfactory. Seems to have slight lag in motion of aircraft which you could get used to. 4	Trimmed very nicely. Could go right on target and hold on target. F_s just a little higher than I like. 2	All aspects affected by damping. Excessive response to initial F_s due to damping characteristics. Aircraft too loose and response too quick on initial application of F_s. General feel - could be improved in damping. 5
h F_s over- ility , re- . 7	Light F_s/V gradient. F_s/g satisfactory. Little hard to trim. Response initially tended to overcontrol in going into turn because of light F_s gradient. Satisfactory once in turn. Reach and hold g satisfactory. Tracking satisfactory. Push-over and pull-up response quite light. 3	Trims well. Handles well in turn. Tracking in turn smooth. Holding g excellent. Tracking ground target not quite as good as holding g, little tendency to overcontrol but still good. 2	Easily trimmed. Aircraft feels solid and moves to where you want to put it. F_s tend to be little light in making pull-ups so you tend to come up to your g rather rapidly. 2	Trimmability not bad unless ruffled by air. Static stability seems to be slightly negative. Damping is very soft which combined give it poor handling qualities. Applying g's have small F_s requirements. 7
as rac- 8	Very lightly damped. F_s/g satisfactory. Frequency low enough to control nose position but uncomfortable to fly and unsatisfactory for tactical. Not easy to track. Reaching and holding g not comfortable because of oscillation. Push-over and pull-up satisfactory except for inability to stabilize on g. 6	Trimmability little difficult. Holding g difficulty because forces vary when trying to hold constant g. Tracking in turns not too bad. Little slow to respond and slight tendency to overcontrol. Tracking in dives not too bad. 6	Aircraft tends to oscillate when trying to bring it to a particular attitude. 7	Trimmability poor. Difficult to remain in trim because of poor damping and excessive oscillatory motion. Response too sensitive for initial F_s application. Reaching and holding g - undesirable due to poor damping. Entry and recovery from turns - oscillatory. Tracking in dive marginal due to initial force input and response. Once settled down it's easier to control. General feel unsatisfactory for tactical. 7
ng and g un- r fighter. ult 7	Trimmability satisfactory. F_s satisfactory. Frequency is quite low and damping relatively poor. No tendency to try to drive it or overcontrol it. Response shows oscillatory motion in trying to stabilize in turn. Frequency is low enough you can usually damp out oscillation. Could also do it on sensitive accelerometer when rapidly changing targets. You run into problems with low frequency. 5	Little difficult to settle down at precise trim. F_s light. Tendency to overcontrol when trying to hold steady g because force changes after applying g. Slight oscillation present in all maneuvers. General feel satisfactory but little hard to control precisely. 4	Easy to trim. Flies well. Usually have one oscillation before getting right on ground target. Can get right on air target. 2	Trimmability satisfactory. Remain in trim satisfactory. F_s acceptable initially; final part of motion tends to initiate unacceptable oscillation of aircraft. Reaching g satisfactory; holding g unsatisfactory due to tendency to overshoot. Entry and recovery from turns oscillatory. Push-over OK but tracking is oscillatory. General feel- tactically unsuitable. 7
tar- l. ponse vy for get. 3	Trim difficult to get set up but remains on good. Response quite slow. Find yourself trying to hurry aircraft with change in F_s. End up having high F_s in entries, then reduction in F_s. Cannot hold fine tracking, other maneuvers not too bad. General feel fairly sluggish. Poor aircraft for tactical maneuvering. 5	Trimmability satisfactory. Wide trim speed band. Just about deadbeat. Slight tendency to have to apply more control once I get g's. F_s fairly light. Aircraft seems little sluggish. Seems to be a little lag of aircraft to control during tracking in dive. General feeling fairly easy to handle but little slow to respond. 5	Easy to trim. Very easy to handle. Goes where you want it, no overshoot. You can put it right on target. 1	Holds trim fairly well except when hitting turbulence. Appears to have neutral static stability, very poor damping. No pronounced tendency for oscillation. Response of aircraft unnatural. Reach and hold g OK. Track OK although a little bit sloppy. Generally unsatisfactory for tactical as medium bomber. 6
or 9	Short period quite slow and damping close to neutral. F_s quite high in initial part of motion, then motion becomes a continually oscillatory mode. Tendency to overcontrol, continually fighting aircraft. In maneuvers aircraft wants to diverge; you have to watch how much control you put in. Can't really track with aircraft. 8	Doesn't seem we have long enough time to trim. Poor damping and light F_s give tendency to overshoot g, seems to almost diverge. Tracking in turns and on target not as bad as holding g. Stick motion not noticeable. Aircraft responds fairly well but poor damping gives rating of 6. 6	Took a while to trim. Tend to get oscillation whenever you start maneuver. F_s are not hard. Once oscillations have settled down, you can hold target fairly well until disturbed again. 7	Trimmability and holding trim poor due to damping. Oscillatory motion excessive about trim. F_s for sudden application of force are too light with airplane response correspondingly too sensitive. Reaching g good, holding g unsatisfactory. Entry and recovery from turn too oscillatory. Tracks poorly in dive due to oscillation. General feel one of discomfort, fatigue-inducing. 8
trol h ch ot. 9	Very responsive to trim. Apparently high F_s commencing maneuver you realize are due to your forcing aircraft to do what you want to get. Response is very slow. Tendency to overcontrol in all maneuvers. Cannot stabilize in tracking. General feel unacceptable. 7	Difficult to trim. Difficult to fly. F_s are light and aircraft responds steadily and increases pitch-up or push-over as forces are applied, makes it hard to control. Tracking in turns fair if pilot is right on controls but controlling small change in point of aim difficult. Holding g difficult. Susceptible to overcontrol and PIO. 9	Easy to trim but more sensitive. F_s are light and when applying g you tend to just dig in slightly. Aircraft flew fine when making smooth small corrections. Just a little too sensitive, though. Tracking difficult because of overshoot and digging in. 6	Easy to trim but difficult to maintain. Slow oscillations induced by attempt to maintain trim by yoke. Initial F_s application induced too abrupt an aircraft initial response. Very low frequency oscillation in tracking and turns requiring low frequency damping by pilot. Not dangerous, but very tiring and difficult tactically. 7

SHORT-LOOK COMMENTS (CONTINUED)

CONFIGURATION	PILOT M	PILOT N	PILOT O
15 $\omega = .4$ $\zeta = .2$	Trimmability satisfactory. Damping fairly poor. F_s in initial part of any motion appears satisfactory. Reach and hold g OK; however, oscillate about g once obtained. Entry and recovery from turns OK. Seems to be follow-up lag in aircraft. Differentiation between control position tracking in turns and dives compromised by poor damping. Push-overs and pull-up OK. 5	Trimmability fair. F_s satisfactory. Aircraft response to initial stick input unacceptable because it's very abrupt. Once steady in turn, no more problem. Reach and hold g OK except right around 1 g. You don't have control over initial response as well as you should. Track in turns and dives poor, continual small oscillations no good for gunnery. General feel unacceptable. 6	Trimmability very good. Damping of short period not very good. Oscillation gave trouble when tracking in turns and in dive, more trouble in dive. 3
16 $\omega = .4$ $\zeta = .3$	Essentially same comments as Configuration 15. However, frequency appears a little bit lower and general feel of aircraft is better. 3	Easy to trim. F_s a little high for my liking. Aircraft response good. Flies very nicely. Tracking was surprising since I kept overshooting back and forth; other maneuvers OK. I didn't think I would have the trouble in tracking. General feel excellent. 2.5	Trimmability good. Trimmed quickly and stayed. Damping good but would be happier with just a little more. Tracking good. As a whole didn't really like it. Seems little sluggish or little heavy. 4
19 $\omega = .4$ $\zeta = .5$	Damped satisfactory. Period slightly long. Turns OK. On push-over to 250 mph, ability to get on target quicly compromised. Getting a delayed response. Appears to be a step change in force gradient. In order to stay on target oscillation frequency is just a little too high. 3	Pretty easy to trim. F_s light, good on initial part but appear high at 2 g. Holding g is quite easy. Entry and recovery from turns satisfactory. Tracking in turn and dive poor particularly in dive. Short rather rapid oscillation which you tend to overcontrol. General feel satisfactory. 3	Trimmability good. Long time to trim down fine. Damping good but slow. Turns and tracking in turns and dives pretty good, among best seen. Complained about slow damping (low frequency). Don't like to have to wait for oscillation to damp. 3
22 $\omega = .3$ $\zeta = .2$	Trimmability compromised by aircraft dynamics. F_s too light, frequency too high. Track in turn and dive lousy. Response isn't good but you can hold relatively constant g with lot of attention. Too much attention to provide damping. 7	Took some effort to trim. F_s heavy initially but not proportionately heavier to go to higher g. So I didn't like it. Maneuvers OK as long as you use smooth controls. General feel of aircraft poor. If you make normal control movements you get a little PIO set up. 5.5	
23 $\omega = .3$ $\zeta = .4$	Trimmability good. F_s appear light. Aircraft response OK. Frequency just little low but damping appears OK. Reach and hold g good. Apparent lowering in F_s gradient here is appreciated and would be desirable in aircraft such as this. Maneuvers OK. Slight overshoot in push-over and pull-ups. Increased frequency of damping would make it a little bit better. 3	Trimmability fair. F_s higher than I like. Maneuvers OK. Initial forces for small changes were higher than I liked, and I had a very slight tendency to overcontrol. General feel good. 3	
26 $\omega = .3$ $\zeta = .8$	Trimmability good. F_s good. Aircraft lags behind control somewhat. Not bad for this aircraft, though. Reach and hold g good. Maneuvering force gradient is light and I like it. Maneuvers good. No undamped oscillation. 3	Trimmability good, little bit slow. F_s initial part - good but maneuvering over 1 g gives impression of F_s lightening. Seems to be lag in aircraft response. Impression of F_s lightening may be just due to lag in response. Maneuvers OK except for this delay in response. 3	Trimmability not very good. Neutrally or slowly negative static. Tracking good in turns and dives if kept close to where wanted, but if it gets away, it's a problem to get back. 6
27 $\omega = .2$ $\zeta = .3$	Any trimmability almost by accident. 2 - 3 knot band. F_s and poor damping make this pretty lousy. Response seems to lag behind stick but pulse input can provide damping. During maneuvers, you must supply own damping. Response in push-over and pull-up appears to be divergent oscillation. Frequency is not so high that it can't be damped. 8	Not too difficult to trim but wouldn't hold. F_s/g and F_s for initial part of response OK but aircraft response seems to lag pilot input so there's tremendous tendency to overshoot and get oscillation going. Very easy to get away from you. Any maneuver with aircraft would be unsafe, very bad, borders on dangerous. 9	Trimmability not good. Takes long time to trim. Neutral or slowly negative statically. Frequency was so low, not really seeing what I wanted to see. Don't like it, bad. Tracking wasn't good but could hack it. Nose didn't move as rapidly as I wanted. 5
28 $\omega = .2$ $\zeta = .5$	Trimmability very poor. F_s appear satisfactory. Aircraft response away from trim not too good, appears statically unstable. Maneuvers fair. General impression - bad. 6	Trimmability extremely poor. F_s light initially, causes immediate response, wants to overshoot. Must reverse controls on rapid pull-up to 2 g to avert overshoot. Entry and recovery from turns not quite as bad due to application of back pressure. Push-over and pull-up response too quick. General feel - very bad, almost dangerous. 9	

SHORT-LOOK COMMENTS (CONTINUED)

CONFIGURATION	PILOT A	PILOT B	PILOT C
1 $\omega = .8$ $\zeta = .2$	Easy to trim, stays at trim. High F_s to make airplane move, easy to hold g. Oscillation in tracking at any attempt to adjust point of aim. Feels overly stiff. 6	Trims well. Rapid response to control. Slight hunting and tendency to overcontrol in tracking and recovery from g, but no hunting while trimming. 3	Trim fair. Response good, quick and lively, with quite a bit of overshoot. F_s medium to heavy. Tracking fair, bobbles but damps out. 4
3 $\omega = .8$ $\zeta = .5$	Trim easy and precise. Responds very closely to control inputs, no delay. Easy to reach and hold g, no oscillation. Easy to track, slight oscillation for abrupt corrections. F_s moderate, would like less build-up in F_s with speed. 2	Trims well. Could get desired g well. Response motion and time good. Could acquire and maintain target well, good response time in recovery. Oscillatory motion nil while trimming, but shows in tracking and maneuvering. Not enough to be undesirable. 2	Trims good, maintains trim OK. Response good, medium lively, no lag or overshoot. Tracking good, response excellent, no problems in pull-out. F_s light to medium. 2
5 $\omega = .6$ $\zeta = .2$	Trims fairly easy. Responds fairly well to control. F_s moderate to heavy to start maneuver, then nose oscillates around desired g. F_s varies during oscillation. Easy to acquire target, but small oscillation in tracking. 4	Trims fair. Response slow, with delay. F_s high at first, then light, then heavy. Oscillation in maneuvers and tracking, difficult to maintain target. Excessive stick travel. 7	Trim OK. Response OK except weak damping, wiggles in pitch. Tracking can be done with effort. Nose bobbles around, so tracking not good. F_s a little high. 5
6 $\omega = .6$ $\zeta = .3$	Trims very easy. Responds well to control, positive but perhaps little slow. F_s moderate to heavy. Easy to get and hold g. Tracking pretty steady. 3	Trims poor to bad. Acquire and hold g fair, but F_s first high, then low, then high again. A little slow to acquire target, tracking some bobbling but fair. Recovers in steps. Excessive stick travel comes with varying forces. 6	Trims quite easily. Response quite good, goes right to where you want it, smooth. Damps quickly. Easy to hold steady g. Tracking good, if disturbed, got small excursion but damped well. Feels good. F_s moderate. 2
7 & 8 $\omega = .6$ $\zeta = .5$	Trims exceptionally easy, maintains trim well. Responds quite well, a little slow, but nose moves with F_s. Easy to reach and hold g. Easy to acquire target. Slight bobble at first then steady in tracking. F_s moderate. 3(1)	Trims fair (good). Rapid response, F_s desirable. Easy to acquire and hold g. Tracking fair. Ability to acquire and hold target fair to good. Slight overshoot on g in pull-out. Complains slightly of F_s a little light (heavy) in recovery. 4(2)	Trim fairly easy and quick, maintains trim well. Response good; lively and smooth, deadbeat, feels good. Easy to get and hold g. Tracking real easy, a real joy. F_s medium. (small pitch oscillation, damps out quick). 2(2)
9 & 10 $\omega = .5$ $\zeta = .2$	Trims easy, maintains trim well. F_s moderate, responds well, although a little slow. Hard to acquire g due to oscillation, but quite easy to maintain mean g. Oscillates during tracking, following corrections. 4(4)	Trim good. Response rapid and good. Acquire and hold g good, but shows oscillation. Tracking difficult due to oscillation. F_s feels good at trim, only slight bobble, but appears variable, first light, then heavy, then light in maneuvers and tracking. 5(5)	Trims with some difficulty in finding trim. Maintains trim OK. Response adequate; not lively, not sluggish. Oscillates a little around desired g. Tracking not precise due to oscillation of nose, can damp with real effort. F_s average, varies some. General feel average, not desirable. 4(5)
12 $\omega = .5$ $\zeta = .4$	Trims very easy. Responds well, feels good. F_s light to moderate. Easy to reach and maintain g, oscillation very well damped. Easy to acquire target, very easy to track. Easy to hold g in recovery. 1	Trim good. Quick response to get started, then lag to stop motion. However, could reach and hold g. Tracking good, but nose tends to keep rising after recovery is started. Conscious control effort required to stop motion. 4	Trims OK, maintains trim OK. Response good, quite lively, but bobbles some. Easy to get and hold g, but a little slow for fighter. Tracks well, but pilot has to fly it. Recovery is good. Generally feels good, damping is adequate. 2
14 $\omega = .4$ $\zeta = .1$	Trim not difficult, maintains trim well, but oscillates for every correction, hard to damp. Initial response good, then motion stopped, then picked up again. Could maintain mean g, hard to acquire exact g. Oscillates. Tracking hard because of oscillation. Disliked varying F_s during motion. 6	Trim poor to fair. Holds trim OK but bobbles for every correction. Response seems delayed in starting, then bobbles, hard to damp. Tracking unacceptable because of overcontrolling and bobble. F_s heavy at first, then lighter. 8	Trims OK, holds trim OK, but oscillatory. Response OK, but high F_s to start motion, then oscillates. Can hold g OK except oscillates around g. Tracking no good, bobbles all the time. Pilot tends to reinforce oscillation. F_s high. 6

LONG-LOOK COMMENTS

Note: Ratings and comments in parentheses are for repeat evaluations.

CONFIGURATION	PILOT A	PILOT B	PILOT C
15 $\omega = .4$ $\zeta = .2$	Trim easy. Responds well except oscillates. Hard to acquire and maintain g, hard to track because of oscillation. Responds to initial control motion, then slows down and speeds up. Feels like roller coaster. 7	Trims poor. Holds trim OK, but oscillates while trimming. Can get and hold g slowly, but overcontrol and oscillate for abrupt maneuvers. Same for tracking: too much bobble. F_s variable, heavy, then light, then heavy. 6	Trims OK, stays trimmed fairly well. Oscillates in turbulence. Response smooth, medium slow, wish it were faster. Oscillates about desired g. Tracking no good because of oscillation, sometimes reinforced by pilot. F_s moderately heavy. 8.5
16 & 17 $\omega = .4$ $\zeta = .3$	Trim easy. F_s moderate to light. Responds very well, some effort to make it move. Slight oscillation. Easy to maintain g, slight rebound in reaching g. Fairly easy to acquire and hold target, although small oscillation. Small rebound during recovery. Slightly sluggish to start motion. 3(4)	Trim good. Response time satisfactory, though shorter time desirable. Could get and hold g, slight oscillation, damped quickly. Could acquire and track target well, but small oscillation, especially for abrupt corrections. Some overshoot of g and oscillation on recovery. 4(6)	Trim pretty good, apparently not well defined. Response adequate, not real lively. Slight delay in getting moving. Tracking fair to poor because of oscillation when disturbed. F_s moderately heavy, not bad. Feel average, could be better. 3(3)
19 & 20 $\omega = .4$ $\zeta = .5$	Trims easy but does not maintain trim very well. Responds well, follows controls almost exactly. Easy to reach and hold g. Easy to acquire and hold target and adjust point of aim. Would overshoot sometimes. F_s light to moderate, light during tracking. 2(1)	Trim good. Response good; a little slow but solid. Little slow to get g, otherwise good. Tracking good, nose stays put, no oscillation, but F_s seems heavy. 3(4)	Trim OK (not too easy, not well defined). Response good, goes where you want it, very little oscillation. Easy to maintain g. Tracking good, very slight overshoot, damps quickly. Precise and nice to fly. F_s fairly light. 2(2)
22 $\omega = .3$ $\zeta = .2$	Trim easy, oscillates in corrections. Response quick to initial control, then slow for additional control, overshoots. Not comfortable to acquire and hold g. Oscillates in tracking. Cannot hold g steady in recovery. F_s light enough but varies, light, heavy, light again. 6	Trim good. Heavy F_s to start maneuver, then must fight it. Initial response rapid, then builds up. Hard to maintain g because nose wants to keep going up. Tracking nil, hard to stop oscillation. Feels spongy, mushy. F_s feels light in recovery, then overshoot g. Excessive stick motion. 9	Can trim pretty well, however, slow returning to trim, and oscillates. Difficult to reach g, oscillates around g. Feels that it is not going to do what you want it to. Tracking difficult, wallows and oscillates. Overshoots g on recovery. Feels poor. 7
23 & 24 $\omega = .3$ $\zeta = .4$	Trims easily but does not maintain trim well. Responds slow but smooth, slight oscillation. F_s light then heavy. Could hold g, but overshoot getting it because motion continues once started. Tracks fair to good, some oscillation. F_s light in tracking. 4(2)	Trim fair to poor. Response time good. Can reach and hold g easily, no overshoot or oscillation. Tracking fair to good, slight oscillation. In recovery, motion starts then delays. Requires varying F_s to compensate. 2(4)	Trims OK (fair). Response fair to good, well damped. A little overshoot, but can maintain g. Tracking easy, holds target, but sluggish to move. F_s reasonably light (moderate). General feel acceptable (barely adequate). 1(3)
26 $\omega = .3$ $\zeta = .8$	Trim easy, but does not maintain trim well. Pretty good to reach and hold g, overshoot some because keeps moving after controls stopped. Stays in whatever attitude it is left. Tracking easy and steady. F_s light. 3	Trim seems good, steady, but hard to find trim. Quick response, although requires large stick travel, then wants to keep moving. Hard to hit g, because nose keeps moving. Tracking fair; can hold target, but motion continues after you expect it to stop. Same in recovery. Requires large F_s to stop motion. 7	Trim a little difficult, not well defined. Response OK but peculiar. Responds to control then damps and stops. Holds g and tracks well, very steady. F_s moderate except very high in tracking and maneuvering. 2
27 $\omega = .2$ $\zeta = .3$	Quite easy to trim. Responds fairly slowly to controls, oscillations damp slowly. Initial response too quick then overshoot g, oscillate around it. Pilot aggravates oscillation. Tracking no good, hard to avoid oscillation. Recover in steps. F_s feel very light, then stiffen with g. 8	Trim very bad. Very bad to dangerous if g applied abruptly. No idea of what g you will get. Tracking nearly impossible. Pilot fights airplane and induces oscillation. 9	Trim not too bad but does not maintain trim speed. Response slow, get more motion than you want. Hard to hit g, keeps moving, oscillates, hard to damp out without overcorrecting. Feels uncomfortable, it wants to get away. F_s not bad. 8
28 & 29 $\omega = .2$ $\zeta = .5$	Not very good to trim. Responds quickly, then keeps moving and overshoots. Pilot effort produces oscillations. Very difficult to track because of overshoot. F_s very light to moderate. 6(6)	Trim difficult to dangerous. Feels like teeter totter. Won't hold trim. Response lags after control applied, then response keeps building. Pilot effort then produces oscillation. Responds slowly then overshoots. Very bad for slow careful maneuvers; dangerous for abrupt ones. 10(8)	Trim somewhat difficult. Response slow, sluggish, but peculiar. Get large excursion from input. Damps slowly, no oscillation. Tracking not good, wallows, tough to get back on target. Pilot gets out of phase. Feels weird, feel disconnected from airplane. F_s fairly light. 8(7)

LONG-LOOK COMMENTS (CONTINUED)

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